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An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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Aveling & Porter, Ltd., ROCHESTER. 1809

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E. J. Davis, M.I.Mech.E., Gas Engines Inspected, Tested and Reported upon. Over 25 years' experience. Tel.: Maryland 1736 & 1737. Wire: "Rapidising, London." —Great Eastern Road, Stratford, E. 15. 1794

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HIGH CLASS Machine Cut Gearing FOR EVERY PURPOSE. 1440

THE GLASGOW ROLLING STOCK AND PLANT WORKS. Hurst, Nelson & Co., Ltd., Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK. Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITH WORK, IRON & BRASS CASTINGS, PRESSED STEEL WORK OF ALL KINDS. Registered Office and Chief Works: Motherwell. London Office: 14, Leadenhall Street, E.C. Od3383

Tank Locomotives. Specification and Workmanship equal to Main Line Locomotives. R. & W. HAWTHORN, LESLIE & CO., LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 1865

Spencer-Hopwood & Kirke PATENT BOILERS. *See page 88, Feb. 8.* 1293 Sole Makers: SPENCER BONECOURT, LTD., Parliament Mansions, Victoria St., London, S.W.

Æ Tubes, Plates, Rods, &c., in Brass and Copper. ALLEN EVERITT & SONS, LTD., Kingston Metal Works, SMETHWICK, BIRMINGHAM. 1344

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Bever, Dorling & Co., Ltd., BRADFORD. HIGH-CLASS ENGINES FOR ALL PURPOSES, also WINDING, HAULING, AIR COMPRESSING and PUMPING ENGINES. 1896

GOLD MEDAL-INVENTIONS EXHIBITION-AWARDED Duckham's Patent Suspended WEIGHING MACHINES—EAST FERRY ROAD ENGINEERING WORKS COMPANY, LTD. LONDON, E.—Hydraulic Cranes, Grain Elevators, &c. See Illus. Advt. last week, page 15. 1715

CRANES. All Types. GEORGE RUSSELL & CO., LTD., Motherwell. 1567

Telegrams:—"Cylinders," Birmingham. Weldless-Steel Tubes for Water-tube Boilers, Superheaters, Shafting, Hydraulic Work, Boring Rods, &c. TUBES LIMITED, BIRMINGHAM. O3179

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Campbells & Hunter, Ltd. SPECIALISTS IN Drillers & Boring Machinery for Engine Works and Boiler Shops. DOLPHIN FOUNDRY, LEEDS. 4547

VOSPER & CO., LTD., PORTSMOUTH. SHIP & LAUNCH BUILDERS, Od 3551 ENGINEERS & BOILER MAKERS.

For Your Repairs or any SPECIAL MACHINERY, try THOMAS HUNT & SONS, Albion Ironworks, Bridge Road West, Battersea, S.W. 11. Est. 1854. 1792

The Mitchell Conveyor and TRANSPORTER CO., LTD., CONTRACTING ENGINEERS. DESIGNERS and BUILDERS of all Classes of HANDLING MACHINERY. Atlantic House, 45-50, Holborn Viaduct, London, E.C. 1. Telegrams: "Micontraco, Cent, London." Telephone: Holborn 2822. 1713

Dredging Plant— For ALLUVIAL GOLD, PLATINUM & TIN, HARBOUR, RIVER & CANAL.—Gravel Dredgers, SCREENS.—DREDGE BUCKETS & Parts, all sizes. ARTHUR R. BROWN, 84, New Broad Street, London, E.C.2. Telephone: London Wall 3413. 1814

RAILWAY AND TRAMWAY ROLLING STOCK. Hurst, Nelson & Co., Ltd., THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3383

P. & W. MacLellan, Ltd., CLUTHA WORKS, GLASGOW. MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION. RAILWAY IRONWORK, BRIDGES, ROOFING, &c. Chief Offices: 129, Trongate, Glasgow. Od 3547 Registered Offices: Clutha House, 10, Princes St., Westminster, S.W.1.

Patent See's Hydro-Pneumatic Ash Ejector Great saving of labour. No noise No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4336

Penningtons, University TUTORS, 264, Oxford Road, Manchester. Estab. 1876. Enrol now for I.C.E. and I.M.E. Postal Courses. 100 per cent. passes last Exams. Reinforced Concrete—a new comprehensive course under expert engineer, £3 3s. Write for particulars. 1711

Iron and Steel Tubes and Fittings. Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 817 The Scottish Tube Co., Ltd., HEAD OFFICE: 34, Robertson Street, Glasgow. See Advertisement page 79.

Royles Limited, ENGINEERS, IRLAM, MANCHESTER. FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, STEAM and GAS KETTLES, Howe's Patents. Merrill's Patent TWIN STRAINERS for Pump Suctions. SYPHONIA STEAM TRAPS, REDUCING VALVES High-class GUNMETAL STEAM FITTINGS. WATER SOFTENING and FILTERING. 5738

IRON & STEEL Tubes AND Fittings AND Steel Plates. STEWARTS AND LLOYDS, Ltd. GLASGOW - BIRMINGHAM - LONDON. See Advertisement, page 27. 1873

FOR SALE. PORTABLE RAILWAY Mounted on STRONG STEEL SLEEPERS. 20 lbs. Section. 2 ft. Gauge. All Good. 1000 TONS Ready to Deliver. THOS. W. WARD, LTD., SHEFFIELD. C 833

ON ADMIRALTY LIST. John Kirkaldy, Ltd., London Office: 101, LEADENHALL ST., E.C.3. Works: BURNT MILL, near HARLOW, ESSEX. Makers of Evaporating and Distilling Plants. Refrigerating and Ice-making Machinery. Feed Water Heaters. Evaporators. Fresh Water Distillers. Main Feed Pumps. Combined Circulating and Air Pumps. Auxiliary Surface Condensers, &c., &c. 1566

The Glasgow Railway Engineering Company, GOVAN, GLASGOW. LTD., London Office—12, Victoria Street, S.W. MANUFACTURERS OF RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES. CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 1948

Regent Guillotine Shears and Power Presses FOR SHEET AND PLATE WORKING. THE REGENT SHEET METAL MACHINE TOOL CO., LTD., REGENT WORKS, WAKEFIELD. 1668

Metallography with the Super-microscope Paper read by Dr. Rogers, November 13th, before the Sheffield Metallurgical Society. See page 98.—F. DAVIDSON & CO., 29, Great Portland St., London, W.1.

YARROW & CO. (1922), LTD., GLASGOW. LAND AND MARINE YARROW BOILERS. 1553

John Bellamy Limited, MILLWALL, LONDON, E. GENERAL CONSTRUCTIONAL ENGINEERS. 1316 Boilers, Tanks & Mooring Buoys STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

Head, Wrightson & Co., LIMITED. See Advertisement page 33, Feb. 8. 2402

Matthew Paul & Co., Ltd., LEVENFORD WORKS, Dumbarton. 1483 See Full Page Advt., page 40, Feb. 1.

Taylor & Challen Presses For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER. Foundry, Works, and Showrooms: BIRMINGHAM. See advert., page 63, Feb. 1. 8195

Cement.—Maxted & Knott, LTD., Consulting Cement Engineers, ADVISE GENERALLY on proposed Cement Schemes FOR ENGLAND AND ABROAD. ADVICE ONLY. Highest References. Established 1890. Address, BURNETT AVENUE, HULL. Cablegrams: "Energy, Hull." 1526

Railway Switches and Crossings T. SUMMERSON & SONS, LIMITED, DARLINGTON. 1312

Plenty and Son, LIMITED. STATIONARY, STEAM AND MARINE ENGINEERS. NEWBURY, ENGLAND. 1851

WAYGOOD-OTIS LIFTS 1415 54 & 55, FETTER LANE, LONDON, E.C.4. 62 & 63, LIONEL STREET, BIRMINGHAM, and Principal Provincial Cities and Abroad.

HEAT INSULATION. CELITE PRODUCTS CORPORATION, Windsor House, Westminster, S.W.1. 1675 See our Illustrated Advertisement, Feb. 8.

If It Must Be Light, Make it of Aluminium. *Data from British Aluminium Co., Ltd., 109, Queen Victoria St., London.* 13

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

University of London.

A Course of Six Lectures on "PRACTICAL HYDRAULIC ENGINEERING PROBLEMS IN CONNECTION WITH NAVIGATION" will be given by Mr. O. C. A. VAN LIDTH DE JEUDE, C.E., (Formerly Civil Engineer to the Nederlands Government Public Works Department, and now Technical Managing Director, Nederlands Harbour Works Co.), at the INSTITUTION OF CIVIL ENGINEERS, (Great George Street, Westminster, S.W.1), on Mondays, Wednesdays, and Fridays, FEBRUARY 25th, 27th, and 29th, and MARCH 17th, 19th, and 21st, at 5 p.m. SYLLABUS: Dredging and Dredging Plant: Brushwood constructions: River Improvements in the Nederlands: Harbour Engineering abroad: Shipping Conditions in Port: the Zuiderzee Scheme. The Lectures will be delivered in English and illustrated with lantern slides. ADMISSION FREE, WITHOUT TICKET.
EDWIN DELLER, C 896
Academic Registrar.

Correspondence Courses for

Inst.Civil Engrs., Inst.Mech.E., London Univ. (Matric., Inter., B.Sc.), and All ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., etc., Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 55, SOUTH JOHN STREET, LIVERPOOL. 1993

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1879

TENDERS.

TO LAUNDRY ENGINEERS.

The METROPOLITAN ASYLUMS BOARD invite

Tenders for the Installation of

a NEW CONTINUOUS DRYING MACHINE at the South-Eastern Fever Hospital, Avonley Road, New Cross, S.E.14, in accordance with the Specification and Drawing prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E. Engineer-in-Chief. The Specification Drawing and Form of Tender may be inspected at the Office of the Board, Victoria Embankment, E.C. 4, on and after Tuesday, 19th February and can then be obtained upon payment of a deposit of £1. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender sent in accordance with the instructions on the Form of Tender and after the Specification and the Drawing have been returned.
Tenders, addressed as noted on the Form, must be delivered at the Office of the Board no later than 2.30 p.m. on Wednesday, 27th February, 1924.
(By Order) G. A. POWELL,
Clerk to the Board. C 899

COUNTY BOROUGH OF GRIMSBY.

ELECTRICITY DEPARTMENT.

The Corporation are prepared to receive

Tenders for—

SPECIFICATION No. 120,
STEAM AND OTHER PIPEWORK.

The Specification comprises H.P. Steam, Feed, Water, Drain and Circulating Water Pipes for connecting up a 3000 Kw. Turbine, Two Boilers, etc., and alterations to existing pipework in connection with the extensions now being carried out.
One Specification and drawing may be obtained gratis from the undersigned, and extra copies of same on payment of 7s. 6d. each.
Tenders are to be despatched so as to arrive not later than Monday, March 3rd.
W. A. VIGNOLES.
Corporation Electricity Works,
Grimsby.
February, 1924. C 913

CITY OF BIRMINGHAM WATER DEPARTMENT.

The Water Committee of the Corporation of the City of Birmingham are prepared to receive

Tenders from Competent

Firms for the MANUFACTURE and SUPPLY of about 1820 lineal yards of SOCKET AND SPIGOT STRAIGHT PIPES with a finished internal diameter of 33 in. The pipes are to be of steel and are to be lined by centrifugal method internally and covered externally with concrete or other approved material.
There will be in addition a number of special pipes.
Specifications and Forms of Tender may be obtained from the Secretary of the Water Department, Council House, Birmingham, on payment of a sum of £1 1s., which amount will be refunded on receipt of a *bona fide* Tender.
Sealed Tenders on the form provided for the purpose, addressed to "The Secretary, Water Department, Council House, Birmingham," and endorsed "Frankley New Reservoir, Contract No. 9," should be delivered at the Secretary's Office on or before Noon on Thursday, February 28th, 1924.
The Water Committee does not bind itself to accept the lowest or any Tender.
F. W. MACAULAY, M.Inst.C.E.,
Chief Engineer.
J. H. BROADLEY,
Secretary.
Water Department,
Council House, Birmingham.
13th February, 1924. C 935

THE GREAT INDIAN PENINSULA RAILWAY COMPANY, 48, COPTHALL AVENUE, LONDON, E.C.2, invite

Tenders for :—

1.	Bells, Bib Cocks, &c. ...	Fee 10s.
2.	Lamps & Fittings	,, 5s.
3.	Leather Belting, &c.... ...	,, 5s.
4.	Ferro Prussiate Paper ...	,, 2s. 6d.
5.	Spring Steel	,, 10s.
6.	Sieves, &c.	,, 2s. 6d.
7.	Galvanised Wrought Iron Water Tubes, &c.	,, 10s.
8.	Brass & Iron or Steel Screws, &c.	,, 10s.
9.	Platelayers' Tools	,, 5s.
10.	Helical Springs	,, 10s.

Tenders are due by Eleven a.m. on 26th February, 1924. Tender forms obtainable at above address. Fees not returnable. C 935

CITY OF NOTTINGHAM.

THE WORKS AND WAYS COMMITTEE are prepared to receive

Tenders for the Supply of the

Undermentioned STORES and MATERIALS, the Contracts to commence on the 1st April, 1924, and to terminate on the 31st March, 1925.

A Cement.
B Blue Lias Lime.
C Red Bricks.
D Blue Bricks.
E Timber.
F Stoneware Pipes, etc.
G Stoneware Pipes, etc. (patent joints).
H Iron Castings, Iron Gulleys, etc.
I Yorkshire Flags, Kerb, etc.
J Granite Setts, Kerb and Broken Granite.
K Ironstone Slag, Chippings, etc.
L River Gravel.
M Concrete Sewer Tubes.
N Picks, Shovels, Scoops, etc.
O Ironmongery.
P Scavenging and other Brushes.
Q Disinfectants.
R Refined Tar.
S Pitch.
T Creosote Oil.

Forms of Tender may be obtained on applying to Mr. T. WALLIS GORDON, City Engineer and Surveyor, Guildhall, Nottingham, on payment of a deposit of 5s. each, which will be returned on receipt of a *bona-fide* Tender in accordance with the Specifications, providing such Tender is not withdrawn and is delivered by the time stated below.
Patterns and Samples may be inspected at the Easteroft D-pot, London Road, Nottingham.
The Committee will not consider any Tender except on the authorised Form of Tender, which must be delivered to the undersigned, in the official envelope provided, on or before Thursday, 6th March, 1924.
The lowest or any Tender will not necessarily be accepted, and Tenders will only be accepted from persons who conform to the conditions as regards paying the local standard rate of wages, etc., and to the working rules of the Nottingham District, applicable to the various trades.
By Order,
W. J. BOARD,
Guildhall, Nottingham. Town Clerk.
11th February, 1924. C 901

APPOINTMENTS OPEN.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

The Department requires the

Services of a Director

of RESEARCH for Research into BUILDING MATERIALS and METHODS OF CONSTRUCTION.
Candidates should possess high general scientific qualifications with research experience and be capable of co-ordinating and controlling the work of a scientific staff. Importance will be attached to architectural-engineering experience.
The Department would be prepared to offer an inclusive salary not exceeding £1200 per annum to a suitably qualified candidate.
Applications, giving particulars of age, qualifications, war service, etc., and enclosing copies of testimonials and/or names of referees, should be made in writing not later than Saturday, March 1st, to the SECRETARY, DEPARTMENT OF SCIENTIFIC and INDUSTRIAL RESEARCH, 16, Old Queen Street, S.W.1. C 838

Applications are Invited

for a VACANCY as SCIENTIFIC ASSISTANT in the Experimental Department of H.M. Signal School, Royal Naval Barracks, Portsmouth. The duties are concerned with the development of Receiving Apparatus for Wireless Telegraphy. Experience of W/T Reception is essential. Preference given to candidates possessing an Honours Degree in Physics and Research Experience.
The Salary is £350—20—450 plus Civil Service Bonus which at present increases £250 to £399 1 0. The Federated Universities' Superannuation Scheme is applicable.—Applications giving full particulars of the Candidate's experience, war service, etc. should be addressed to—THE SECRETARY OF THE ADMIRALTY (C.E.), Admiralty, S.W.1, not not later than 23rd February. C 770

Wanted, Manager for Engin-

eering Works engaged upon Internal Combustion Railway Cars.—Address, stating full experience and salary, C 890, Offices of ENGINEERING.

Manager Wanted for

Engineering Works in the Midlands engaged on Colliery plant and constructional engineering work.
Must have had good experience in similar capacity preferably in similar works and be of proved abilities coupled with initiative and drawing office experience. Excellent scope for suitable man.
Replies, which should give fullest particulars of experience and copies of testimonials or references, with salary required, to be addressed to C 884, Offices of ENGINEERING.

Wanted, Two First-class Men

for Estimating and Ratefixing used to instrument work and toolmaking. Only those with a thorough practical experience and accustomed to laying out sequence of operations and speeds and feeds need apply. State age experience and salary required. —Address, C 823, Offices of ENGINEERING.

The Royal Air Force

REQUIRES ELECTRICAL FITTERS, FITTERS AERO ENGINE, FITTERS GENERAL WIRELESS OPERATORS and POWER STATION TRADESMEN. Age limits:—Ex-service men 18 to 30; Non Ex-Service 18 to 26; men highly skilled in certain trades up to 35; ex-N.C.Os. up to 38 (with rank according to trade ability). Pay from 24/6d. to 66/6d. per week, on enlistment, and all found. Allowance for wife and children to men 26 and over.—Write, stating age, or call:—
INSPECTOR OF RECRUITING, R.A.F.,
4, Henrietta Street, Covent Garden,
London, W.C.2. C 485

Wanted, by Firm of Metal

Plate Workers, FIRST-CLASS MAN for Estimating; must be fully capable of working from Drawings and Conducting correspondence. Age about 30.—Address, stating age, experience and salary required, C 907, Offices of ENGINEERING.

Locomotive Fitter.—Wanted,

for Sugar Estates, East Africa, Good WORKING FITTER, accustomed to running repairs, three years' agreement.—Write, stating age, experience, wages, to BOX K.T., c/o DAVIES & Co., 95, Bishopsgate, E.C. 2. C 897

Ratefixer Required, London

District, must be thoroughly familiar with all up-to-date production methods and used to the HIGHEST CLASS production in quantities. Must also have held similar position previously.—Address, stating age, full details of experience (names of firms, etc.) and salary required, C 908, Offices of ENGINEERING.

Sales Engineer Required,

London District, with knowledge of Power Plant Instruments, for calling on Power Stations, Consulting Engineers, etc. State full particulars, salary, connection, experience.—Address, C 923, Offices of ENGINEERING.

Wanted, Experienced Engi-

NEER to take charge of power station condensing plant design; thoroughly competent good technical training, quick calculator, able to handle correspondence. London.—Address, stating age, qualifications and salary required, C 929, Offices of ENGINEERING.

PORT OF LONDON AUTHORITY.

Applications are Invited for

the POSITION of MECHANICAL ENGINEER.
Candidates must not exceed 45 years of age, and must be fully qualified members of the Institution of Mechanical Engineers, with wide experience in the design, construction, maintenance and running of the mechanical equipment of Docks and Harbours, including Electrical and Hydraulic Installations, Pumping, Refrigerating and Grain Discharging Machinery, Cranes, Conveyors, Locomotives, Lock-gate Machinery and Bridges, etc.
Applications, giving particulars of experience, qualifications, etc., and stating salary required, must be on the prescribed form obtainable from the Staff Manager, Port of London Authority, E.C. 3, and be delivered not later than the 31st March, 1924.
Any canvassing of Members of the Authority by or on behalf of an applicant will entail the application being ignored.
F. AYLIFFE,
Secretary. C 926

Applications are Invited

for the POST of ENGINEER to take charge of design at H.M.S. "VERNON," Portsmouth.
Salary £900, rising by annual increments of £15 to £500 and full Civil Service Bonus, which at present increases £300 to £432.
The bonus corresponds to a cost of living index figure of 75 per cent. and is subject to increase or decrease by 1 26th for every five points rise or fall in the index figure.
Applicants should have a sound knowledge of electro technics and physics; a sound knowledge and experience in design and use of electrical apparatus as applied to modern acoustics; and should be capable of supervising initial manufacture and testing of designs.
Experience in Research or Experimental work will be taken into consideration.
Applications should be forwarded to the SECRETARY OF THE ADMIRALTY (C.E. Branch), not later than the 1st March. C 933

Assistants (Three)

REQUIRED by the GOVERNMENT OF HONG KONG for service in the Public Works Department, for a period of three years with possible permanency. Salary £460 per annum, rising by annual increments of £20 to £600 per annum and thence (if appointment is made permanent), to £950 a year, plus a strictly temporary exchange allowance of 20%. The salary is converted into dollars at the Government rate of exchange, at present fixed at two shillings to the dollar. This rate is open to revision. Conveyance allowance of $240 per annum is paid. Free passages provided.
Candidates, unmarried, 24 to 30 years of age, must be fully qualified Architects' Assistants, well up in building construction and drainage work, able to make surveys and to take levels. Those possessing a knowledge of the law relating to buildings, public health and easements, and who have had experience in the administration of Building and Public Health Byelaws preferred.—Apply, at once, by letter, stating age, qualifications and experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting at head of application the reference number M/12921. C 928

Applications are Invited

for a VACANCY as JUNIOR SCIENTIFIC ASSISTANT in the Experimental Department of H.M. Signal School, R.N. Barracks, Portsmouth. The duties are concerned with the development of Receiving Apparatus for Wireless Telegraphy. Experience of W/T Reception is essential. Preference given to candidates possessing an Honours degree in Physics and research experience.
The salary scale is £175-15-235 plus Civil Service Bonus, which at present increases £175 to £272 8s. The Federated Universities Superannuation Scheme is applicable.—Applications, giving full particulars of the candidate's experience, war service, etc., should be addressed to THE SECRETARY OF THE ADMIRALTY (C.E.), Admiralty, S.W.1 not later than the 7th March. C 934

Assistant Works Manager.—

Advertisers, Box C 638, acknowledge with thanks the numerous replies to their recent advertisement.
Interview appointments will be made with suitable candidates. C 917

Power Engineer.—Required

for Works in Midlands, ENGINEER competent to take charge of Power House, including complete electrical installation, heating, lighting, electrical pumps and synchronous set, also steam-driven pumps, hydraulic accumulators and Boiler Plant.
Apply by letter, giving full particulars as to training, qualifications, age, experience and Salary required.—Address, C 893, Offices of ENGINEERING.

Electrical Engineer,

thoroughly capable, with sound technical and practical experience, REQUIRED as Assistant to Chief Mechanical Engineer. Experience in modern colliery practice an advantage. State full experience, age and salary required.—C 937, Offices of ENGINEERING.

London Merchant Firm

REQUIRE the SERVICES of an ENGINEER with thorough knowledge of machinery for export abroad.—Age not more than 35. Sal. £500-750 p.a. according to qualifications.—Apply, LAURIE & CO., Employment Specialists, 38, Basinghall St., E.C.2. No preliminary fee. C 912

Wanted, Engineer as

Assistant Works Superintendent. Must have good experience in running H.P. Air Compressors. Slight chemical knowledge and managerial experience an advantages.—Address, giving age, experience and salary required, C 905, Offices of ENGINEERING.

Wanted, Young Engineer,

unmarried, resident in London, preferably with some knowledge of Chemical engineering, to push sale of speciality among consulting engineers and large works.—Write, stating age and qualifications, to BOX E.156, WILLING'S, 119, Moorgate, E.C.2. C 910

Armstrong Siddeley Motors

Ltd., invite APPLICATIONS for the position of HEAD DRAUGHTSMAN in charge of motor-car design under Chief Engineer.—Address applications to MANAGING DIRECTOR, ARMSTRONG SIDDELEY MOTORS, LTD., Parkside, Coventry. C 926

Wanted, First-class

DRAUGHTSMAN with thorough knowledge of Hydraulic Machinery and Shipyard Tools. Good salary and permanent position to suitable man. Only fully qualified and experienced men need apply, stating age, salary required, experience, etc.—Address, C 921, Offices of ENGINEERING.

A Large Engineering Firm

in the Manchester District REQUIRES the SERVICES of an Efficient and Capable DRAUGHTSMAN on Steam Turbines, preferably having had experience on Land Machines. Applications are invited from first-class men who should write with full particulars as to age, experience and salary required.—Address, C 911, Offices of ENGINEERING.

Wanted First-class Draughts-

MAN for structural and mechanical work on Coal and Coke Handling Machinery. Good structural experience essential. Reply, giving full particulars including age and salary required to—STRACHAN & HENSHAW LTD., Engineers, Bristol. C 884

Draughtsman Required,

thoroughly experienced in Aerial Ropeways. State full particulars of experience, age and salary required, etc.—Address, C 904, Offices of ENGINEERING.

Chief Draughtsman Required,

thoroughly experienced in Aerial Ropeways. State experience, age and salary required.—Address, C 903, Offices of ENGINEERING.

First-class Draughtsman

WANTED for North of England, with experience in the design and construction of large Winding and Hauling Engines, Steam and Electrically driven.—Address, giving particulars of experience, age and salary required, C 900, Offices of ENGINEERING.

Wanted, by a Firm of

Constructional Engineers, in London, a Competent Draughtsman. State age, experience and salary required.—Address, C 930, Offices of ENGINEERING.

Draughtsman Required

Temporarily in London to prepare drawings for large Railway Sheds and general constructional work.—Address, C 912, Offices of ENGINEERING.

PORT OF LONDON AUTHORITY.

Applications are Invited for

the POSITION of CHIEF DRAUGHTSMAN.
Candidates must not exceed 45 years of age and must be capable of organizing and controlling the staff of a large Drawing Office. They must have had a thorough experience in the design of bridges, caissons, gates and dock entrances, and general dock and railway construction and equipment work, and also experience in the preparation of Charts, Reductions and Enlargements.
Applications giving particulars of experience, qualifications, etc., and stating salary required, must be on the prescribed form obtainable from the Staff Manager, Port of London Authority, E.C.3, and be delivered not later than the 31st March, 1924.
Any canvassing of Members of the Authority by or on behalf of an applicant will entail the application being ignored.
F. AYLIFFE,
Secretary. C 925

First-class Tracer Required

for large Constructional Steelwork Engineers' Drawing Office. Man about 30. Only those with first-class knowledge of steelwork details need apply, others useless.—Address, giving full particulars of age, experience, salary required and when free, C 909, Offices of ENGINEERING.

SURFACE YIELD FROM A HYDROGRAPHICAL BASIN.

THE amount of water running off a hydrographical basin due to the rain falling on it, which may be termed its surface yield, is defined as that portion of the rain falling on the basin which remains on or near the surface of the ground too short a time to be taken up or lost by evaporation; a varying portion of this is underground flow, but that which is subsoil flow in one place may appear as surface flow in another. As the slow movement of ground flow tends to equalise the variations in rainfall, the flow is fairly constant for any drainage area and largely governs the low-water flow of any basin; the freshets are caused by the irregular manner in which the rain falls on the basin. The geological and physical characteristics of the basin, and the temperature of the locality also influences the yield. Temperature affects rainfall and evaporation, and low temperatures exert a further effect mainly on the distribution of flow by forming ice and snow, and temporarily storing the precipitated moisture.

The yield from a hydrographical basin is measured either as a per cent. of the rain falling on the basin; or the losses for any period of time usually a year, are estimated, or are ascertained by observation of the stream flow of the basin, and the difference between the rainfall and the losses in the yield from the basin. The conditions which influence the yield are, the amount and intensity of the rain falling on the basin, the slope of the ground surface, the amount and nature of the vegetation, the climatic conditions obtaining at the locality, and the geological formation. The rain falling on a hydrographical basin is disposed of by (1) transpiration, (ii) evaporation from the soil, and from bodies of water pools and streams, (iii) appears as surface flow in streams or percolates into the soil, and reappears after a varying period of time as surface flow, or percolates too deep to reappear as surface flow, augments the ground water and eventually escapes to the sea, or continues to circulate in the interior of the earth. The greatest losses are due to soil evaporation and transpiration, which depend on the temperature of the locality and the amount of water in the soil (see ENGINEERING, December 3, 1920, pages 727 *et seq.*). In a thoroughly dry surface where the soil in its upper layers is so dry as to be deplete of moisture, evaporation from the soil is reduced to a minimum. Mr. Thorp found at the Munnar Valley, South India, that the greatest scarcity of stream flow occurred after the first heavy rains had fallen at the end of the dry weather; and quotes an example of a small stream, feeding a lake all through the dry weather, failing within four days of the first heavy showers. (Proceedings, Institute of Civil Engineers, vol. clxix, page 367.) Losses from evaporation and transpiration are difficult to estimate, and the most satisfactory method of determining the yield from any basin is to actually measure the discharge of the stream draining it for a considerable number of years, so as to obtain the mean, the maximum, and the minimum discharges that may be expected in the periods into which a year may be divided. To neglect stream gaugings, even if approximately correct, for rainfall records which may be of far greater accuracy, and to estimate losses from imperfect data cannot be considered a satisfactory solution of the problem; but as observations of rainfall are made in all countries, while gaugings of stream flow are few, to determine the relation of yield to rainfall comparison has to be made of obeerved losses in neighbouring basins, which are similar in characteristics and subject to the same meteorological conditions; or actual stream gaugings are made for a few years and compared with the rainfall during the same period. Data of reasonable accuracy showing the distribution of stream flow over several consecutive years are in such cases of more importance than very accurate measurements covering a short period of time. The most satisfactory solution is the installation of a properly constructed stream gauge on the watercourse draining the basin, working continuously for at least seven years; if then the gauge is calibrated for the various stages of flow, it would be possible to compare the yield from a basin due to the rain falling on it for the years for which stream-gauge readings are available, and from the data thus obtained to deduce yields for the years for which rainfall records are available and stream gaugings are not. As a general rule it may be stated that where the annual rainfall on a basin does not exceed 10 in. to 12 in. the whole of it is lost in evaporation and transpiration, and causes no surface flow except when it comes in violent storms. The following table gives approximate yields that may be anticipated in temperate and insular climates such as that of the British Isles:—

Annual Rainfall. 1.	Loss. 2.	Yield. 3.	Yield as a Per Cent. of Rainfall. 4.
in.	in.	in.	
20	12	8	40
30	16	14	47
40	19	21	52½
60 to 70	20	40 to 50	66⅔ to 71½

Column 4 shows that the yield as a per cent. of the rainfall, for the same locality, increases with the rainfall; and there are numerous examples to substantiate the statement. In arid climates the losses are considerably greater. The Helena River (W. Australia), which feeds the Mundaring Reservoir, has a catchment basin of 569 sq. miles, and the yield from the basin compared with the rainfall on it is tabulated below. (Proceedings, I.C.E., vols. clxii and ccv.)

Year.	Rainfall.	Yield.	Loss.	Remarks.
	in.	in.	in.	
1899	27·2	0·2	27·0	Rainfall is taken as the mean between Mandaring and York.
1900	33·2	1·17	32·03	
1901	25·0	0·17	24·83	

Evaporation from water at Perth Observatory was 65·79 in. from July 1, 1901, to June 30, 1902, the maximum being in January 10·22 in., and the minimum in August 1·75 in. The Penner River, South India, with a hydrographical basin of 21,000 sq. miles, and a mean (annual) rainfall of 25 in. on its basin, has a mean yield of 2 in. on its basin.

The maximum continuous yield that may be expected from a hydrographical basin would be the correctly ascertained mean rainfall on the basin less the correctly-ascertained losses, but as years of rainfall in excess, and greatly in excess of the mean enters into the computation for the mean rainfall, and the extreme variations from the mean occur at long intervals of time, large storage would be required to balance these variations. Such storage may be all out of proportion to the advantages gained, and would be costly; moreover, the rain falling in excess of the mean is often due to floods which last for a short period of time, and unless the impounding reservoir is of very large capacity the greater part of the flood supply will be lost; on the other hand, to assume the yield due to the year of minimum rainfall as the available supply would not be making the fullest and most economical use of the yield capacity of a hydrographical basin. The usual practice in this country is to assume as the available supply the annual yield due to the mean rainfall of the three consecutive driest years, and to provide storage sufficient for a number of days varying with the irregularity of the rainfall, and nature of the basin. For non-absorbent areas, if adequate storage is provided, it is usual to assume four-fifths of the estimated mean annual rainfall as the mean of the three consecutive driest years, to deduct from 12 in. to 20 in. as loss, and to assume the result as the yield. Hydrographic basins of sufficient area for present requirements and free from pollution are, in this country, now difficult to obtain; and a larger expenditure to secure a greater yield than that given by the mean rainfall of the three consecutive driest years seems justifiable.

In comparing the yield from a hydrographic basin with the rain falling on it, the period assumed for such comparison is that in which the seasons complete their cycle, which is a year, but it is obvious that the calendar year is not suited for such a purpose, and the period for such comparison should be, what may be termed the water year. The water year should begin when the ground water plane of saturation is at its lowest level, or at its highest level; but as it is not always possible to ascertain the calendar months in which these conditions obtain, the water year is generally assumed to begin when stream flow is at its lowest limit or ceases altogether. If rainfall and yields are tabulated starting from the calendar month, or the next succeeding month, in which stream flow is at its lowest, it will be found that the connection between rainfall and yield is more regular than when tabulated by the calendar year. In the British Isles the water year would begin in September; in India the water year would begin at the end of the dry weather generally about June 1. Assuming the yield of a water year as the "available supply" may not always be reliable, as during certain periods of the year there may be little or no yield, although the total yield of the year may be sufficient for requirements; and a division of the water year into seasonal periods is indicated. From observations of rainfall at a locality for a considerable number of years it is possible, to ascertain the wet and dry seasons, and to divide the water year into periods when the relations of yield to rainfall are markedly different. American investigators divide the water year into three seasons, viz.:—

(1) The storage period during which evaporation and transpiration are small, the yield compared with rainfall large, and during which the ground water plane of saturation reaches its highest level.

(ii) The growing period when evaporation and transpiration are large, the yield is small, and at the end of which period the ground water plane of saturation reaches its lowest level.

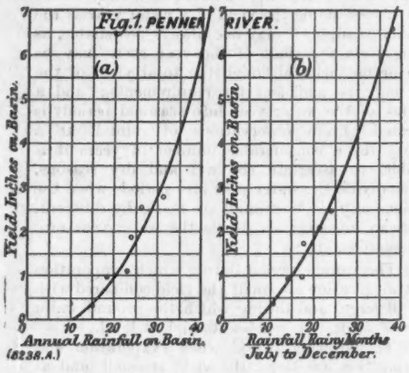
(iii) The replenishing period, when with normal rainfall the ground water plane tends to recover its level, stream flow increases and normal conditions are re-established. The replenishing period would be the beginning of the water year, and in this country would include the months of September, October and November. The storage period would extend from December to March; and the growing period from April to August. In climates of the temperate zone, the ground surface never becomes thoroughly dry except after intense and long-continued drought, which may occur once in thirty or forty years, so that the summer rainfall often influences the annual yield, but the bulk of the annual supply depends on the winter or storage period rainfall. In tropical climates there are generally two distinct seasons of the water year, the "Wet" or rainy season, when the bulk of the annual supply is received, and the dry season, when little or no rain is received, the ground becomes thoroughly dry, and the summer rainfall has little influence on the annual yield. Areas and islands in the equatorial belt have two wet and two dry seasons in a year and consequently stream flow is more certain and regular. In desert areas and arid zones the intensity of each individual fall of rain influences the yield.

The difficulty of comparing the yield from any hydrographical basin with the rain falling on it, is the loss and gain to stream flow due to ground storage. The losses (to stream flow) are due to evaporation and transpiration, which may be termed the climatic losses; and to the loss or gain due to ground storage, which depends on the geological formation of the basin. The action of the ground water on the yield or stream flow may be compared to that of a reservoir which at various seasons of the year augments or decreases it, and this action of the gain or loss to stream flow from ground storage is one of the causes of the variation in the annual yield of a hydrographical basin, and these variations are increased in abnormal seasons. The ground water losses are less important in large than in small areas because a large portion of the rainfall may pass out of a small basin as ground flow, whereas in a larger one a considerable portion of the ground flow is returned to the surface as springs. The loss due to deep seepage, compared with climatic losses is small and may be neglected. As a case in point the yields from the Talla, and the Gameshope Burn basins of the Edinburgh water supply may be considered. (Proceedings of the Institution of Civil Engineers, vol. cxciv.)

The Gameshope basin forms the upper portion of the Talla basin, the Gameshope Burn being the main feeder of the Talla. The statement below compares the rainfall yield and loss shown as inches on the basin, of the Talla basin with that of the Gameshope basin. The water year is divided into the following equal periods :—

R—Replenishing period—August to November, inclusive.
S—Storage period—December to March.
G—Growing period—April to July.

The Talla basin is described as hilly country, the hills being composed of Silurian greywack and shale; the lower slopes of the hills are covered with a sheet of boulder clay; and the upper and steeper slopes with the debris of greywack and shale, along with grit and sand. The description indicates that the upper portion of the Talla basin, that is the Gameshope basin, is more permeable than the lower portion of the basin.



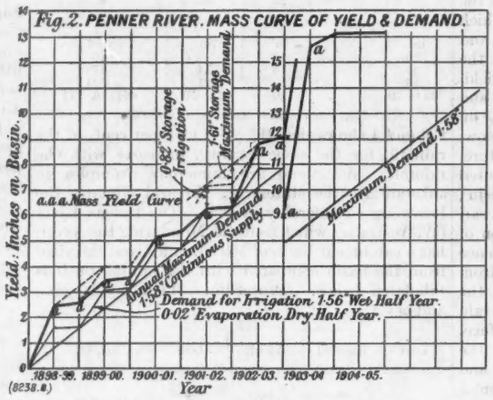


Fig. 2. PENNER RIVER. MASS CURVE OF YIELD & DEMAND.
Yield. Inches on Basin.
0·32" Storage Irrigation
1·61" Storage Maximum Demand
a.a.a. Mass Field Curve
Annual Maximum Demand 1·56" Continuous Supply
Maximum Demand 1·56"
Demand for Irrigation 1·56" Wet Half Year.
0·02" Evaporation Dry Half Year.
1898-99. 1899-00. 1900-01. 1901-02. 1902-03. 1903-04 1904-05.
Year
(8238.B.)

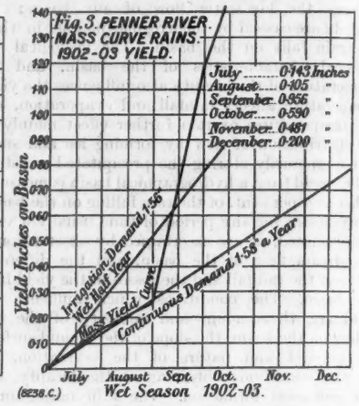


Fig. 3. PENNER RIVER. MASS CURVE RAINS. 1902-03 YIELD.
July ..... 0·143 Inches
August ..... 0·105 "
September 0·856 "
October ..... 0·590 "
November .. 0·481 "
December .. 0·200 "
Yield. Inches on Basin.
Irrigation Demand 1·56" Wet Half Year
Mass Yield Curve
Continuous Demand 1·56" a Year
July August Sept. Oct. Nov. Dec.
Wet Season 1902-03.
(8238.C.)

Year.	Gameshope Basin. 3,000 Acres.				Talla Basin. 6,180 Acres.			
	R.	S.	G.	Total	R.	S.	G.	Total.
1906-07 :								
Rain ..	28·0	14·5	24·6	67·1	25·6	13·0	21·9	60·5
Yield ..	22·2	19·0	16·5	57·7	21·2	19·2	16·3	56·7
Loss ..	5·8	−4·5	8·1	9·4	4·4	−6·2	5·6	3·8
1907-08 :								
Rain ..	27·9	25·5	15·7	69·1	25·3	22·7	14·3	62·3
Yield ..	18·3	25·6	10·9	54·8	19·1	25·1	12·3	56·5
Loss ..	9·6	−0·1	4·8	14·3	6·2	−2·4	2·0	5·8
1908-09 :								
Rain ..	24·1	19·5	17·8	61·4	21·9	18·0	16·8	56·7
Yield ..	16·1	19·3	13·9	49·3	16·6	19·8	15·2	51·6
Loss ..	8·0	−0·2	3·9	12·1	5·3	−1·8	1·6	5·1
1909-10 :								
Rain ..	25·6	20·0	19·8	74·4	23·2	26·4	18·0	67·6
Yield ..	18·2	22·6	7·8	48·6	18·3	28·2	10·6	57·1
Loss ..	7·4	6·4	12·0	25·8	4·9	−1·8	7·4	10·5
1910-11 :								
Rain ..	21·0	22·5	20·4	63·9	19·1	19·0	17·7	55·8
Yield ..	13·4	18·0	9·6	41·0	16·1	21·4	13·5	51·0
Loss ..	7·6	4·5	10·8	22·9	3·0	−2·4	4·2	4·8
1911-12 :								
Rain ..	22·6	35·5	17·2	75·3	19·8	31·1	15·6	66·5
Yield ..	14·7	38·6	11·8	65·1	16·5	28·1	13·3	57·9
Loss ..	7·9	−3·1	5·4	10·2	3·3	3·0	2·3	8·6
Mean of the Six Years.								
Rain ..	24·9	24·4	19·25	68·55	22·5	21·7	17·4	61·6
Yield ..	17·2	23·8	11·75	52·75	18·0	23·6	13·5	55·1
Loss ..	7·7	0·6	7·5	15·8	4·5	−1·9	3·9	6·5

The mean of the six years shows that the yield from the Talla basin is greater than that of the Gameshope basin, although the latter basin has the greater rainfall. The Talla basin as a whole is more impervious than the Gameshope basin, and at the Talla reservoirs the ground flow down the valley is intercepted by the impounding dam, so that it seems reasonable to conjecture that the loss to ground water in the Gameshope area is regained at the Talla reservoir. The statement below shows the mean evaporation from a water surface for the years under consideration for the same periods of the water year :—

	Inches.
Replenishing period ...	5·1
Storage	1·3
Growing	10·2
Total	16·6

If the evaporation from land surfaces bears any relation to the evaporation from a water surface, the effect of ground storage augmenting the yield during the growing period, and the depleting the yield during the replenising period is indicated.

In the case of the Burrator Reservoir, Plymouth Water Works, the hydrographic basin lies in granite formation, on the hills the rocks lie close to the surface, but in the valleys the granite is decomposed, the decomposition extending to depths of over 100 ft. The foundations of the reservoir dam are carried down through the decomposed rock to the solid rock below, so that the ground flow is practically intercepted. The loss as observed for the years 1907–08 to 1911–12 is little; the whole rainfall on the basin being received into the reservoirs (Proceedings, Inst.C.E., vol. cxciv). Areas underlaid by permeable beds are not generally considered favourable for the development of a water supply project; but if a suitable site for the construction of a reservoir to impound the drainage from such a basin be obtained, and if the impounding dam be carried down to an impermeable stratum so as to intercept the ground flow, a water supply project may be developed with a reservoir of smaller capacity than would be required if the basin were impervious; as the ground water would be shielded from surface evaporation. If in the higher reaches of the valleys of the basin the ground water plane of saturation was sufficiently below the ground surface the loss from soil evaporation would be small.

The case of a river basin under tropical conditions will now be considered. The Penner River (South India) drains the high lands of the Mysore plateau, and the districts of Cuddapah and Nellore of the Madras Presidency. The river falls from a level of 2,500 ft. above sea level to the coastal plains of Nellore. At Sangam, some 50 miles from the sea, an anicut or low dam is built across the river to divert the water flowing down it into an irrigation canal. The anicut is 7 ft. in height and is built on shallow well foundations, so that the ground flow along the deep sandy bed of the river is not intercepted. The area of the hydrographic basin above the anicut is 21,000 sq. miles, and its geological character consists, in the highlands of Mysore, of granitoid gniess with a thin covering of soil; in the Cuddapah district, of quartzites, limestones and shales, and in the Nellore district of alluvium overlying quartz rock and shistose gneiss. There are no large permeable beds in the basin except the deep sandy bed of the river itself, and narrow valleys filled with talus and debris. The basin contains innumerable tanks or small reservoirs which intercept the supplies to the main stream, so that the surface run-off or yield at the Sangam anicut is uncertain; yet when cyclonic storms sweep over the country the river comes down in alarming floods. Except for thunderstorms and light showers in April and May the bulk of the rain is precipitated in the months of August to December. The months of April, May and the early part of June are hot and extremely dry, the mean temperature over the basin being 90 deg. F. in the shade. Temperatures of 112 deg. F. in the shade have been registered at Cuddapah at the end of May. On the coastal plains of Nellore the sea breeze tempers the heat. During the rainy season the humidity is high and the temperature averages from 70 deg. to 80 deg. F. In the cold weather, January to March, the air is cold and dry, the temperature averaging between 60 deg. and 65 deg. F. The basin lies in the zone of uncertain rainfall. The discharges at the Sangam anicut are taken from the river diagrams prepared by the Irrigation Department and may be accepted as reasonably accurate. The water year is divided into three periods :—

Rains—July to December, inclusive.
Cold weather—January to March.
Hot weather—April to June.

The statement below shows rainfall and yield for the years 1898–99 to 1904–05. The rainfall yield and loss are shown as inches on the basin :—

Year.	Periods. Rains.	Cold.	Hot.	Total.	Remarks.
1898–99 :					
Rainfall ..	21·32	0·0	5·05	26·37	
Yield ..	2·40	0·063	0·046	2·51	
Loss ..	18·92	−0·063	5·004	23·86	
1899–00 :					
Rainfall ..	14·16	0·02	4·31	18·49	
Yield ..	0·91	0·007	0·035	0·95	
Loss ..	13·25	0·013	4·275	17·54	
1900–01 :					
Rainfall ..	17·84	2·23	4·01	24·08	
Yield ..	1·69	0·056	0·094	1·84	
Loss ..	16·15	2·174	3·916	22·24	
1901–02 :					
Rainfall ..	17·56	0·42	5·04	23·02	
Yield ..	0·95	0·047	0·023	1·02	
Loss ..	16·61	0·373	5·017	22·00	
1902–03 :					
Rainfall ..	23·96	1·17	6·23	31·36	
Yield ..	2·477	0·19	0·06	2·73	
Loss ..	21·483	0·98	6·17	28·63	
1903–04 :					
Rainfall ..	37·55	0·49	3·66	41·70	
Yield ..	6·557	0·464	0·039	7·06	
Loss ..	30·993	0·026	3·621	34·64	
1904–05 :					
Rainfall ..	10·39	1·09	Supply practically nil	—	
Yield ..	0·318	0·004		0·32	
Loss ..	10·077	1·086		—	

Arranging the rainfall, yield, and loss in order of magnitude :—

Year.	Rainfall.	Yield	Loss.
1904–05	Say 15	0·32	14·68
1899–1900	18·49	0·95	17·54
1901–02	23·02	1·02	22·00
1900–01	24·08	1·84	22·24
1898–99	26·37	2·51	23·86
1902–03	31·36	2·73	28·63
1903–04	41·70	7·06	34·64

It has already been pointed out that when the ground surface is completely dry soil evaporation is checked and reduced to a minimum. The small losses in 1904–05 and 1899–1900 are due to the rainfall not being sufficient to completely damp the soil, vegetation suffered, and the numerous tanks in the basin received a scant supply. On the other hand the loss of 34·64 in 1903–04 was due to the moist condition of the soil, causing increase vegetation; the tanks were full and there were a greater number of puddles and streamlets all contributing

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

Fig. 1.

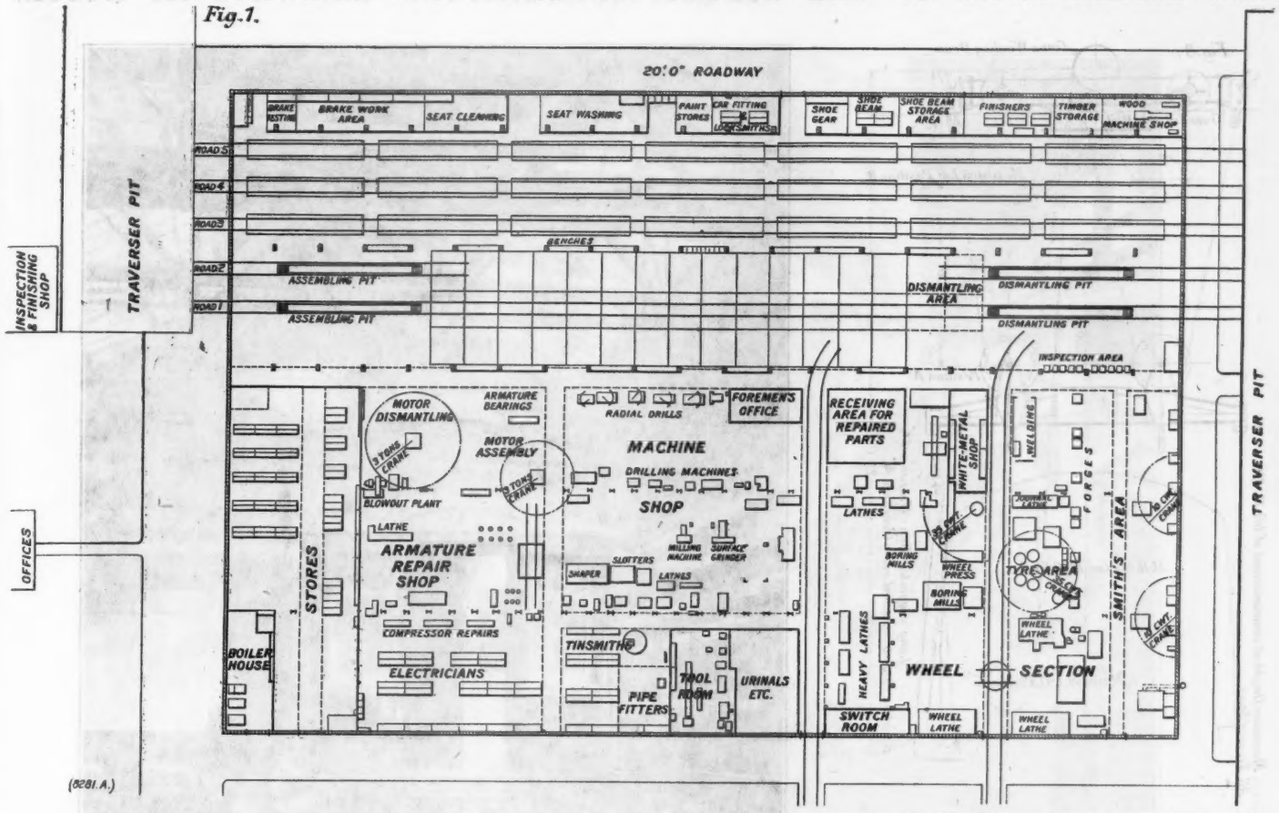
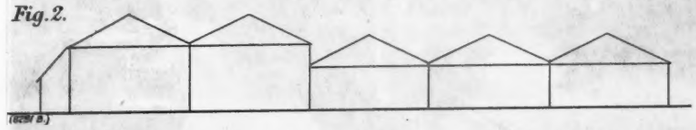


Fig. 2.



to a great loss from evaporation from water surfaces; and the ground water plane, as evidenced by wells, was raised. No account is taken of the ground flow in the deep sandy bed of the river. Owing to the small extent of permeable area in the basin the loss and gain to ground water is small, and it is possible to construct a curve showing the annual yield that may be expected from the basin due to the rain falling on it, *vide* Fig. 1 (*a*). The variations in yield are due to the manner in which the rain falls, and the rainfall intensity, as shown by the wet season rainfall of 1899–1900—July 0·36, August 1·48, September 6·85, October 4·86, November 0·58, December 0·03; total 14·16; yield 0·91—and wet season, 1901–02—July 2·41, August 1·7 September 3·92, October 2·52, November 5·32, December 1·69; total 17·56; yield 0·95. The statement also shows that the wet or rainy seasen dominates the yield, *vide* Fig. 1 (*b*).

Storage.—Few streams or rivers are so regular or constant in their flow that some storage will not be found necessary to balance their irregularities, and the capacity of the impounding reservoirs will depend on the variation in supply. In this country Hawksley's rule gives the capacity of an equalising reservoir for the mean yield of the three driest successive years as $\frac{100}{\sqrt{R}}$ 100 days supply, where R is the mean annual rainfall of the three driest successive years in inches. Hawksley's rule gives rather a smaller reservoir than would be sufficient for present requirements. In the "forties" Mr. G. R. Burnell has stated that experience in this country has shown that a supply equal to six months consumption is required to be stored in the wet season to insure an undiminished distribution in dry weather. The only accurate method of determining the capacity of an equalising reservoir where the necessary records exist is to construct mass curves of supply and demand. As an example, taking the case of the Penner River at the Sanjam anicut, as already observed the bulk of the supply is received in the rainy season and the obvious divisions of the water year would be six months rain and six dry months.

Such a mass curve is shown in Fig. 2—and the maximum demand that can be obtained from the data available is 1·58 in. a year, and the storage required would be 1·61 in. on the basin. The mass curve has been redrawn for the critical period at the end of the water year 1901–02 and the rainy period of 1902–03 in Fig. 3, which shows that owing to the delay in the setting in of the rains the supply just fails. The demand should therefore be reduced. In moderately flat country the water surface area of a reservoir capable of storing a yield of 1·61 in. on an area of 21,000 sq. miles would be about 20 sq. miles, and, neglecting the rainfall on this area, the evaporation from the water surface may amount to 75 in. a year, which is equivalent to 0·071 in. on the river basin. And taking into consideration the slight failure in 1902–03, the annual available supply from the river may be estimated at $1·57 - 0·07 = 1·5$ in. on 21,000 sq. miles. The above calculations are for a constant demand, but in the case of an irrigation project for that part of India when the only irrigated crop is rice, the demand is during the six months June to December. As a partial failure in one year is not a serious matter the demand is taken as 1·58 in. every six months, and under these conditions the required storage will be 0·82 in. (*vide* Fig. 2). Assuming the loss from evaporation from the water surface of this smaller reservoir to be equivalent to 0·04 in. on the basin, the available supply will be $1·58 - 0·04 = 1·54$ in. on 21,000 sq. miles, or 75,460,000,000 cub. ft. a year. Allowing a supply for irrigation at 5 acres of paddy per 1,000,000 cub. ft., the river combined with storage should be capable of irrigating 377,300 acres of paddy land.

ACTON CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS.

THE new shops of the London Underground Railways at Acton are ultimately intended to deal with the heavy repairs to all Underground and Tube rolling stock, though at present they deal only with that of the Metropolitan District, the Bakerloo and the Piccadilly lines, and with the Watford joint stock. The works are the outcome of a decision reached in 1920 to provide central shops and to abolish the separate plants of the several lines forming the system. They stand on property extending to 30 acres, the works and yard running to 28½ acres, while the final covered area is expected to amount to 10 acres. Additional land is being acquired for the extension, which will result in shops about four times the present covered area. On the south side the present building will be able to extend for another seven bays for body and truck work, while on the North a three-bay extension will be possible for the machine shops. On the west side a large shop of eight bays is contemplated; this will be devoted to painting and woodwork. The traverser arrangements and other provisions will naturally be proportionately extended.

At the present moment the first section of the shops is scarcely complete, but the installation is so far advanced that it is in regular operation though some of the methods and details of organisation have still to be perfected. The works are in close contact with the Ealing shops, which in future will be reserved for light repairs, and where as a matter of fact painting is, as a rule, at present done; but eventually cars undergoing heavy repairs at Acton will be completely finished there, as will be gathered from what has gone before.

In establishing these works, the endeavour has been to develop methods of working similar to those adopted at the neighbouring omnibus works at Chiswick Park. Our readers are already familiar

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

Fig. 3.

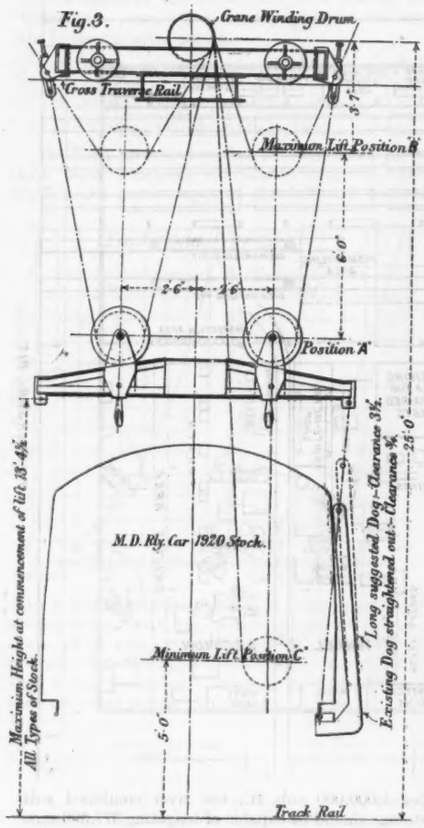


Fig. 4.

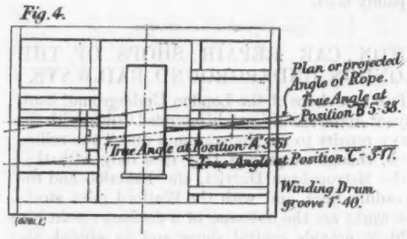

Plan or projected Angle of Rope.
True Angle at Position B 5°38'.
True Angle at Position A 5°51'.
True Angle at Position C 5°17'.
Winding Drum groove 1'40".

Fig. 5. Beam and Tackle used in Lifting Cars.

with these as we gave a description of these works in our issue of February 3, 1922.* The key to the system is the maintenance of a uniform flow of work through the shops organised to suit the length of time required for work on the main units. The development of this scheme in connection with railway car work is a very different matter from the methodical handling of large numbers of comparatively small units conforming to a strictly limited range of standards. The result is that while the basis of operation is practically identical, the railway car shops are not quite so impressive or, we may say, spectacular, as the omnibus repair works previously referred to. They are none the less interesting, though the number of units passing through the shops is much lower, and the work necessitates occasional divergence from the lines which are intended to be regularly followed.

The movement of the work is timed to suit the passage of the car bodies through the shops. Unlike the usual shops, trestles are not provided for these, and they are not allowed to remain stationary while under overhaul, nor are they lifted out when completed from any part of the shop, and taken to the exit by overhead travelling cranes. No large travellers are provided serving the three body repair roads at present in use. The car bodies are mounted on temporary bogies, and as a body is finished at the outgoing end of the shop, it is drawn out and the whole line of bodies standing on that track worked down one stage, and a fresh one inserted at the incoming end of the bay. The psychological effect of this regular movement is said to be considerable, as every effort is made by the several gangs to get their part of the work finished by the time the body is due to be moved on a stage, while the other sections of the shops work to keep up a constant supply of the necessary components, so that at the final stage the body and trucks may be assembled without delay from either side. Without any reflection on the admirable organisation of the works, we may say at once that the system does not work without an occasional hitch. It will be quite evident to engineers responsible for the repair of a variety of coaching stock that all cannot be passed through the works at a uniform rate. The Acton shops of necessity have to handle many varieties of cars, and while large numbers fall very well into the system, there are exceptions which do not lend themselves so well to it. In such cases, it may be that a car still some way inside the shops may be finished before those in front of it, or that owing to the exceptional character of a vehicle and the need for its release as soon as possible, precedence may have to be given to it. These cases are dealt with specially, and though at times they interfere with the routine they do not greatly disturb the general system of work.

At the present time three tracks are allotted to car bodies. Two of these are devoted to motor cars which are longer in the shops than trailers. It will be clear that all trailers and all motor cars will not be likely to take exactly similar times in overhaul, but as they are limited to this small number of tracks there is at present no opportunity for further classification. Early in the extensions it is intended to enlarge the works by the addition of two more bays. These will be utilised for body work, and the present body bay will be fitted with overhead cranes, for which columns are already installed, and utilised for truck work. With six roads then available instead of the present three, it will be manifestly easier to classify the stock so as to secure greater uniformity of movement than is possible at present, though, as far as it has gone, the method adopted has proved eminently satisfactory. The present output of the works is about 20 cars per week, the average time taken in passing them through the shops being five days for trailer cars and eight days for motor cars.

A general plan of the shops is given in Fig. 1, page 195. At present they consist of five bays 400 ft. long and of 50 ft. width. A section of the bays is given in Fig. 2. There is nothing particular to remark about the structural features of the shops. The interior is well lighted and the works give one, at present, the idea of being roomy. Whether this ideal will be always maintained the future can only tell; there is inevitably a tendency, as work increases, to introduce here and there another machine, and crowding too often follows this process before the

* Engineering, vol. cxiii, page 145.

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

(*For Description, see Page* 195.)

FIG. 6. DISMANTLING, ASSEMBLING AND TRUCK BAY.

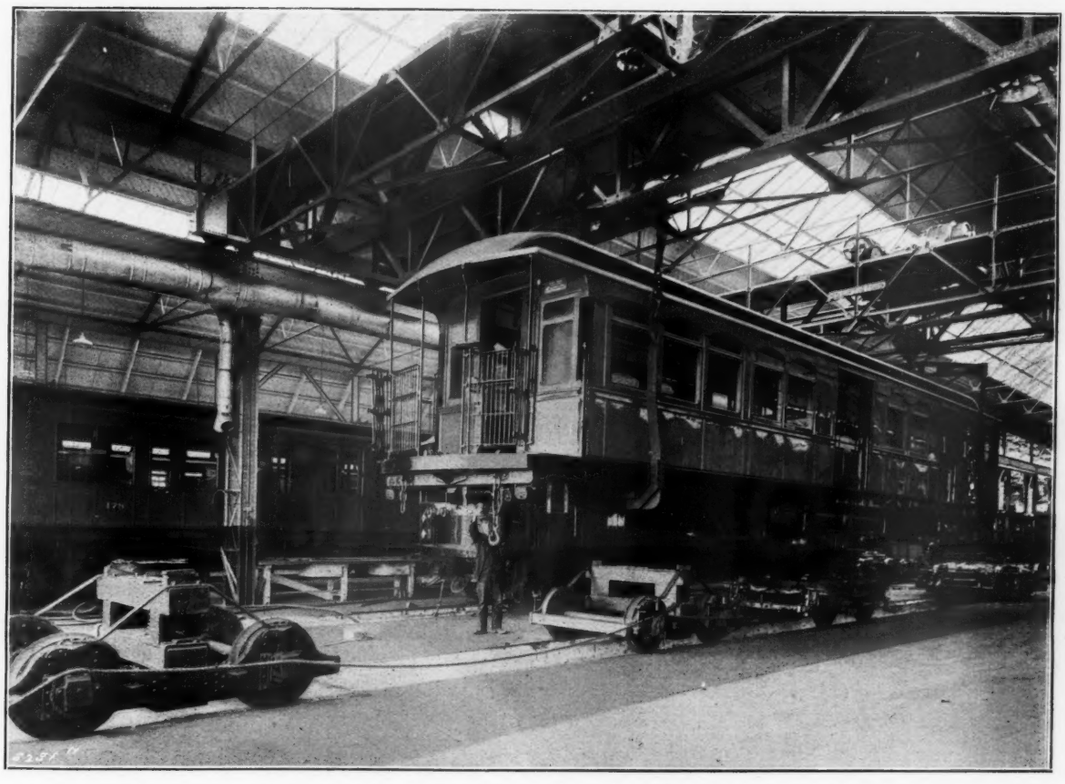


FIG. 7. TRUCKS BEING PLACED UNDER LIFTED CAR.

(*To face page* 196.)

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

(*For Description, see Page* 195.)

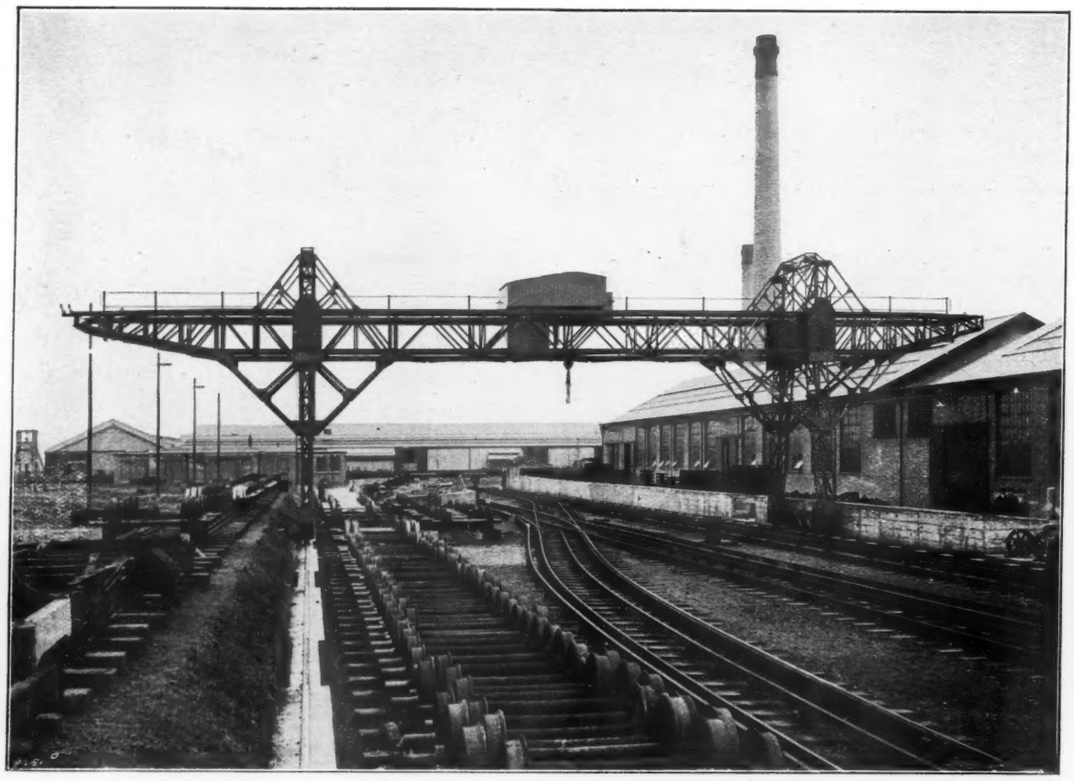


FIG. 8. TRAVELLING CRANE FOR STORES YARD AND WHEEL PARK.

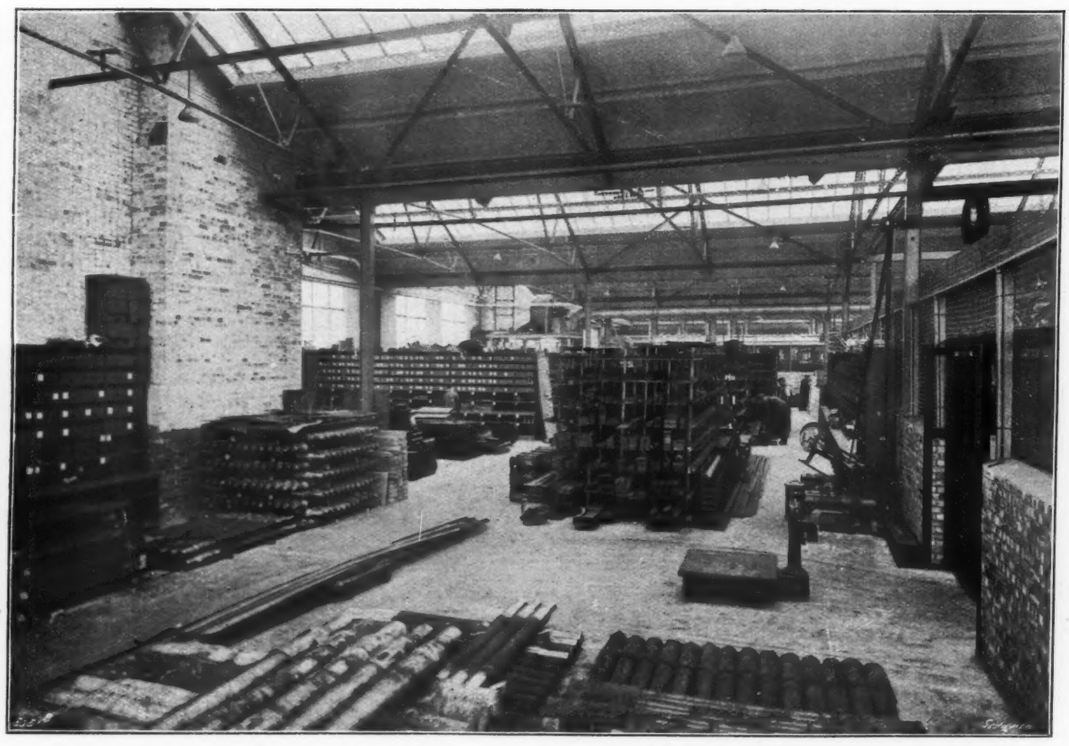


FIG. 9. INTERIOR OF STORES.

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

(*For Description, see Page* 195.)

FIG. 10. THE MACHINE SHOP.

FIG. 11. DOWN-DRAUGHT HEARTHS IN SMITH SHOP.

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

(*For Description, see Page* 195.)

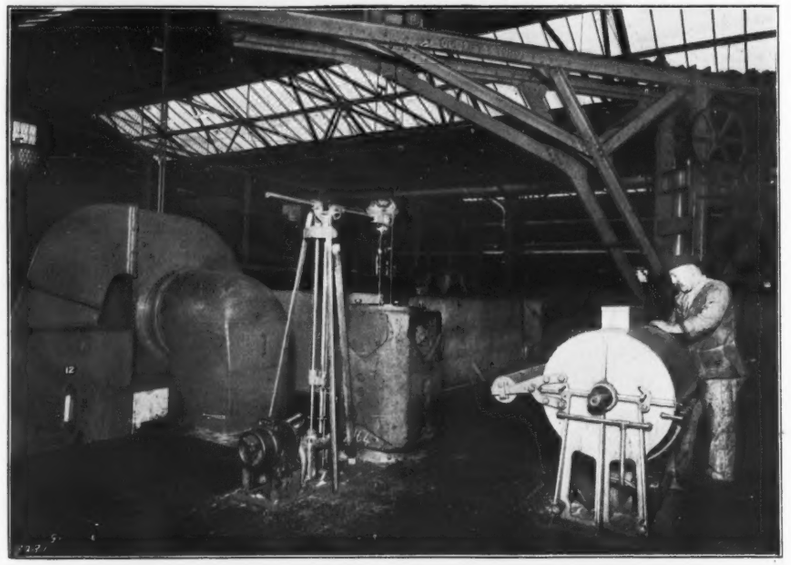


FIG. 12. ARMATURE AND CASING CLEANING PLANT.

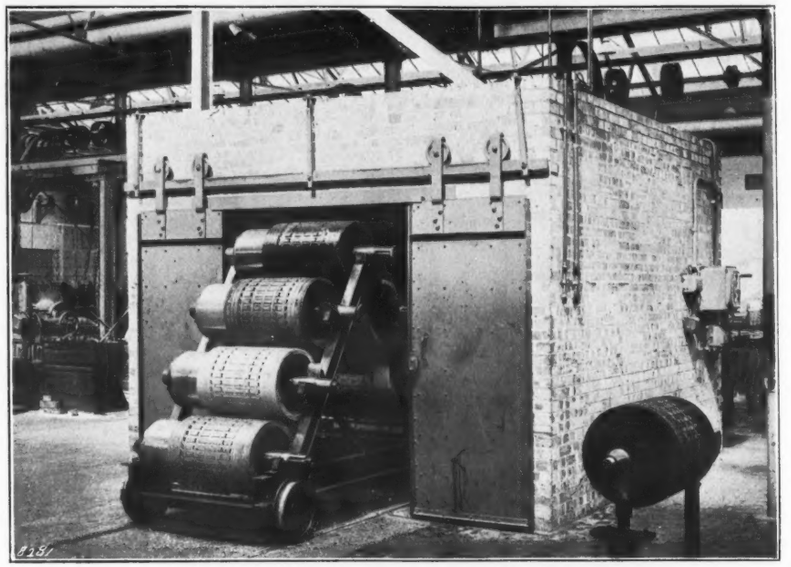


FIG. 14. STOVE FOR DRYING OUT ARMATURES.

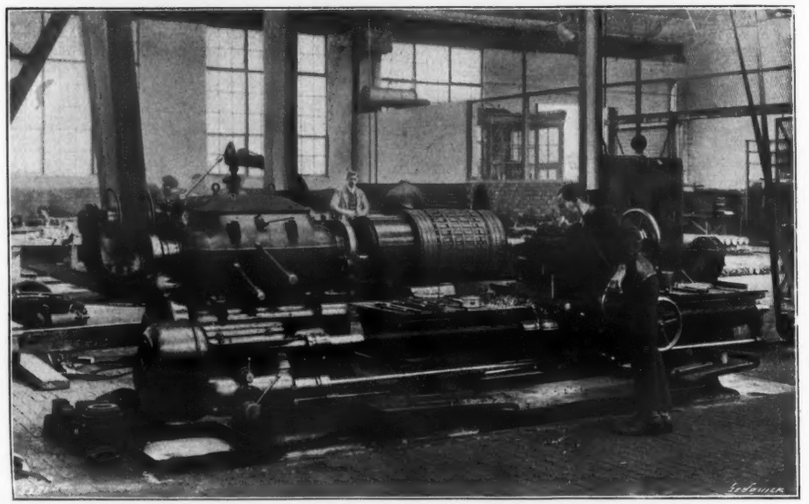


FIG. 13. COMMUTATOR TURNING.

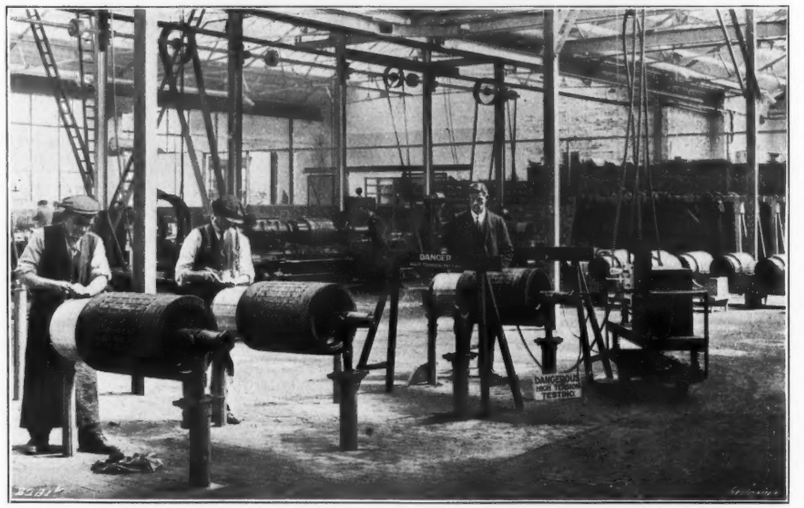


FIG. 15. FINISHING AND TESTING COMMUTATORS.

(*To face page* 197.)

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

Fig. 16.

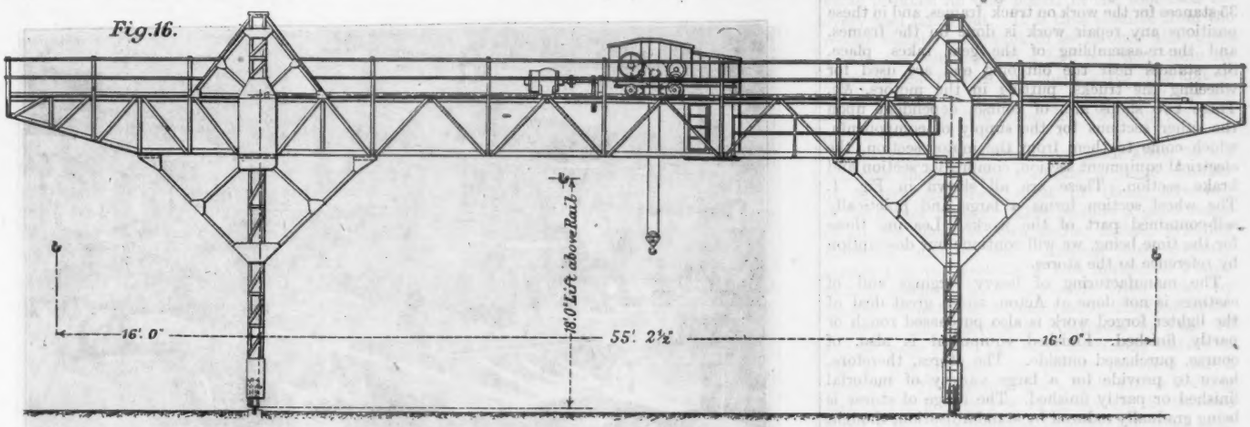
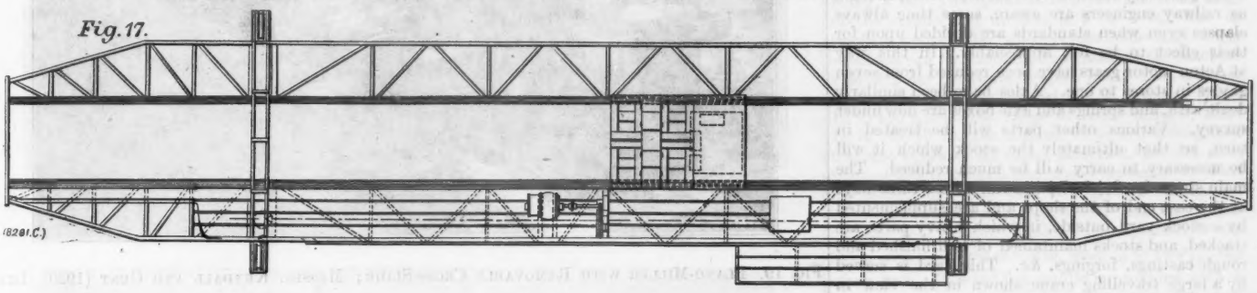


Fig. 17.



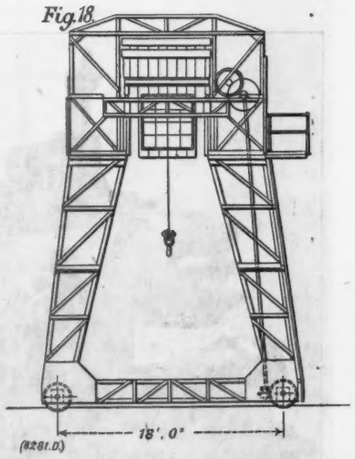
drastic step is taken of expanding the section. At present there is little likelihood of this at Acton. An ample margin of room has been allotted and we understand some sections are rather above than below present requirements.

The shops are split up into well defined sections as will be clear from Fig. 1. As the cars are received from Ealing they are taken on to a 45-ton electric traverser running across the end of the shops. A car is drawn on to this by means of an electric capstan on the traverser, and the latter when loaded is moved to bring the car opposite the stripping bay, into which it is drawn. This operation is performed also by the traverser capstan, the rope being passed over a snatch block on the shop floor. These snatch blocks are on flaps hinged in the floor. When not in use the flap is closed down, leaving a level floor. When required the flap is thrown back and the pulley on its underside now comes uppermost, and is ready for use.

When inside the shop the car is handled by two 15-ton overhead cranes, provided with a special form of lifting beam and long hooks which pass under the solebars. As the bodies are not evenly loaded, on account of the brake and compressor gear, the ordinary centrally-hung beam has been replaced by the special form, shown in Figs. 3 and 4, page 196, and also in the view given in Fig. 5. This will be readily understood. Two large diameter pulleys are arranged some distance apart on each beam, and two lifting ropes are used winding on to one drum on the crane crab. The opposite end of each rope is made fast to the crab frame, the ropes being fitted with screw adjustment to take up any uneven stretching, in order to keep the car body when slung on an even keel. In order to keep the ropes from fouling on the drum the sheaves are canted (Fig. 4). As soon as the car is ready for lifting it is raised by the cranes, the trucks are run out, if necessary with the aid of the capstan, and temporary bogies are run in. The body is lowered on to these, drawn out of the shop on to the traverser, traversed over to one of the tracks in the adjoining bay and there takes up its position at the end of the line of bodies under repair.

The trucks which are left in the shop are stripped by the stripping gang, and the parts are sorted. Practicall, all the small gear is placed on platforms

Fig. 18.



or stillages standing ready, and these, when loaded, are picked up by Ransome run-about battery trucks and taken to the other departments according to routine. Small parts requiring cleaning are sent in this way off to the bosh, motors are taken over to the motor section, and so on. The truck frames are taken in hand in the same bay, and any work required by them in the way of re-riveting or replacements attended to. The wheels are run off on a side track running across the shop to the wheel section, springs are sent off to the spring section, etc. On its return from the washing plant the small work is taken to its proper section or to the fitter's benches, where it is overhauled, to be passed finally to "spares" racks in the shops from which it is taken as required.

As it is not possible for us to follow all the work in detail through the shops we propose to deal with the various sections by themselves, and we may, therefore, conclude this part of our account of the works with a reference to the final assembly at the outgoing end of the finished car. This end of the shop is shown in Fig. 6, Plate X. Here the process described above is reversed. A pair of trucks, it is assumed, is ready near the end of the bay and a body on its temporary bogies finished in the adjoining bay. The body is hauled out on to the traverser, moved on this over to the truck bay, into which it is hauled by capstan and snatch block. The cranes then take hold of the body and lift it till the king pins are clear of the temporary bogies. The two finished trucks are coupled by a standard length of rope and the capstan rope is attached to the leader, a turn being taken round one axle box of both of the temporary bogies, or of the last one only. On the capstan being operated the two finished bogies are drawn under the car, spaced the proper distance apart, while ahead of them the two temporary bogies are drawn out of the way. The body is then lowered and it is checked for height of buffers. The process is illustrated in Fig. 7, Plate X, a view taken, however, before the present lifting beams were put into service.

At this point the car is run out of the shop and taken to a small shop on the opposite side of the traverser track, for finishing. This shop has two pits. Collector gear is here fitted, and electrical equipment, connections, etc., tested, and the whole finally inspected. The provision of this shop greatly relieves the outgoing end of the main shop.

It will be noticed from Fig. 1 that the body bay shows standing room for seven cars on a track. The work done in this shop is divided into four definite stages, each of which has to be completed in turn. In the case of motor cars the first stage consists in high-tension testing, and in stripping control equipment and compressor. The height of the temporary bogies has been chosen with a view to convenience of work of this kind. The second stage consists in overhauling the electrical fixtures and making good faults developed in the Stage 1 testing. In the third stage the compressor and contactors are re-fitted, final adjustments made, and the control tested; while in the fourth the car is inspected and insulation tests are made. For trailer cars the first stage involves high-tension testing and the inspection of bus lines and connection boxes. Stage 2 includes the overhauling of switch panels and making good the defects found in the testing in Stage 1. The third stage covers the overhauling of heating and lighting circuits, while the fourth

is similar to that for the motor cars. The body-work, overhaul of fittings, etc., proceeds as the car works down the shop through these various stages.

The truck bay, shown in Fig. 6, Plate X, provides 35 stances for the work on truck frames, and in these positions any repair work is done on the frames, and the re-assembling of the gear takes place. Six stances near the outgoing end are used for wheeling the trucks, putting in the motors, &c. These two shops are, of course, dependent upon the other sections for the supply of components, which come to them from the motor section, the electrical equipment section, compressor section and brake section. These are all shown in Fig. 1. The wheel section forms a large and practically self-contained part of the works. Leaving these for the time being, we will continue our description by reference to the stores.

The manufacturing of heavy forgings and of castings is not done at Acton, and a great deal of the lighter forged work is also purchased rough or partly finished. Finished equipment is also, of course, purchased outside. The stores, therefore, have to provide for a large variety of material finished or partly finished. The range of stores is being gradually reduced by standardisation, though, as railway engineers are aware, some time always elapses even when standards are decided upon for their effect to be felt appreciably. In this way at Acton motor gears have been reduced from seven grades in stores to one. Axles have been similarly dealt with, and springs and axle boxes are now under survey. Various other parts will be treated in turn, so that ultimately the stock which it will be necessary to carry will be much reduced. The main stores for finished parts run across three bays at the east end of the shops and are supplemented by a stock yard outside, in which heavy parts are stacked, and stocks maintained of half-finished and rough castings, forgings, &c. This yard is served by a large travelling crane, shown in the view in Fig. 8, Plate XI, and in Figs. 16, 17 and 18, page 197. This crane has a capacity of 3 tons. With a span of 55 ft. and a height of lift of 18 ft. it clears four tracks in the yard, while cantilever extensions enable the crab to travel out 16 ft. over an additional track on the north side and a road and stacking space on the side nearest the works. The latter is used for all new stores material not taken actually under cover inside the works. The piles of tyres may be seen standing behind a low concrete wall on the right of Fig. 8. Towards the end of the yard may be seen facing the first, a second low concrete wall. This bounds a floor partitioned off into large sections for scrap of all kinds. Further to the left of this again is a platform which is used for storing reclaimable material, such as worn axles which can be turned down to a smaller standard size, and so on. A view of the interior of the stores is given in Fig. 9, Plate XI. As far as possible parts are finished in the machine shops to stores manufacturing orders so that advantage may be taken of making in quantities. This tends to economy at the machines, etc., and also lessens the movements about the shops.

Before dealing with the individual sections of the shops a few remarks may be made on points which strike one on entering them. As already noted they are light and roomy. The whole interior is heated by a plenum plant with three heating units, delivering warmed air to all parts by means of ducts carried along the rows of columns or under the roof trusses and branched at frequent intervals. The floors are kept clear of work which is all stacked in definite spots, wherever possible, jobs passing through a series of operations are mounted on stillages for easy movement. Some of the shops are partitioned off from the rest, but the interior as a rule has not been divided up in this way. A noticeable feature is the presence of large name boards hung from the roof over the several sections, indicating to what the area below is allotted, as, for instance, "Tyres," "Spare Parts," &c. Throughout the shops excellent provision is made for washing, groups of wash basins with hot and cold water laid on, being arranged at a number of points, while racks are furnished for the accommodation of coats, &c. These features may be noticed in several of our illustrations.

Electric power obtained from Lots-road station is used, taken from the Acton Town sub-station, the supply being D.C. at 600 volts for all machine tools. Individual drives are installed for all the larger machines, but in the machine shop a number of tools are driven off line shafting, as will be seen in Fig. 10, Plate XII. The care with which guards have been arranged for all belting in such cases is well shown in this illustration. For lighting and for tyre heating furnaces, rivet and pipe heaters, three-phase supply is obtained from the transformer house of the neighbouring L.G.O.C. works, itself supplied from Lots-road. For lighting 240-volt current is used, and for heating 420 volts.

Compressed air is supplied in the shops by an electrically-driven compressor of 300 cub. ft. capacity. The compressor is one of the Sentinel pattern by Messrs. Alley and MacLellan, Limited, Polmadie, Glasgow, the 60 b.h.p motor driving it being a Metropolitan-Vickers machine. The set is automatic, cutting in when the pressure falls to 80 lb. per square inch, and being cut out when it rises to 100 lb. It is controlled by a standard car governor, as used on the rolling-stock for the Westinghouse brake. This equipment has proved extremely satisfactory, and the working of the compressor since this control has been added has been improved. A further modification is contemplated with a view to enabling the motor to be started up under no load conditions, instead of full load as at present. The starting panel

THE CAR REPAIR SHOPS AT ACTON.

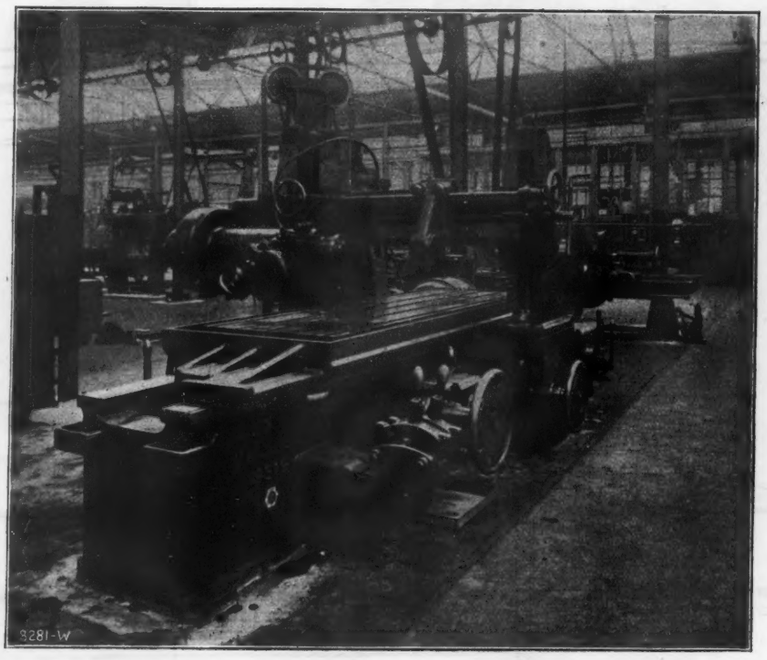


Fig. 19. Plano-Miller with Removable Cross-Slide; Messrs. Kendall and Gent (1920), Ltd.

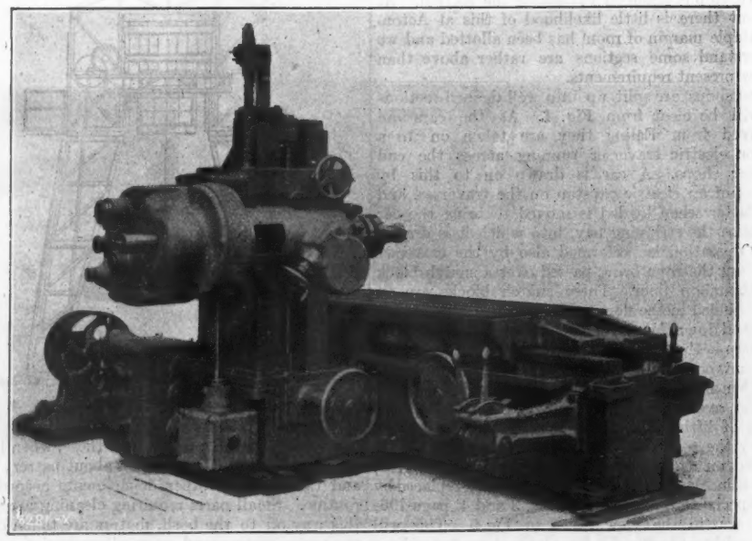


Fig. 20. Plano-Miller with Cross-Slide and Standard Removed; Messrs. Kendall and Gent (1920), Ltd.

THE CAR REPAIR SHOPS AT ACTON.

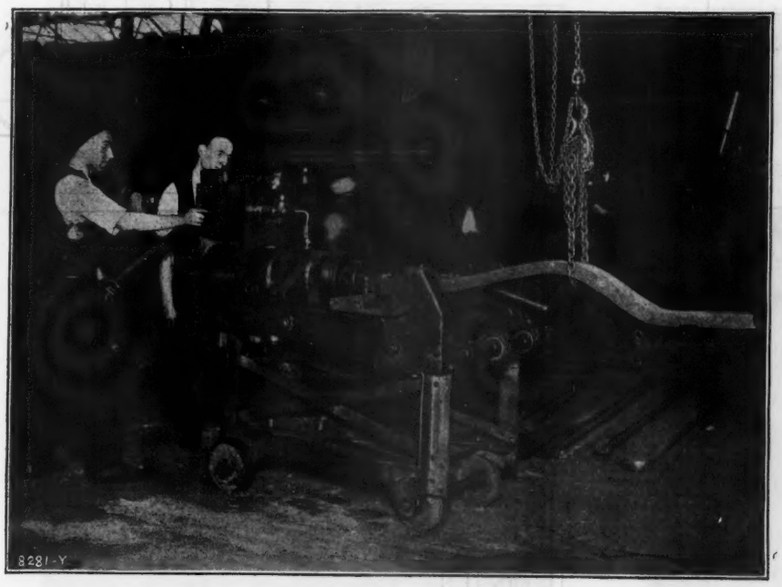


FIG. 21. PORTABLE HYDRAULIC BENDING PRESS.

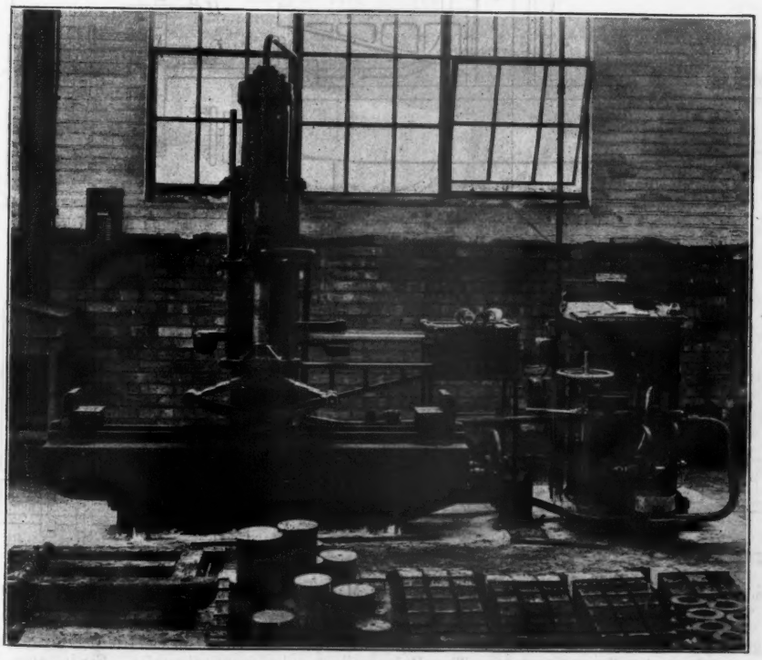


FIG. 22. SPRING TESTING AND SPRAGGING MACHINE; MESSRS. W. AND T. AVERY, LIMITED.

is of the automatic solenoid type by Messrs. Brookhirst Swichgear, Limited.

In commencing to deal with the several sections it is not feasible to take them in any particular sequence, since work proceeds simultaneously in all, and gravitates towards the outgoing end. We may, however, fittingly commence with the tool-room, which is comparatively small. At the present time it is occupied developing standard jigs, but this work is not undertaken on a large scale. The shop contains a Gisholt and a Lumsden curved lip tool grinder. Tools are ground from bar stock. Standard shapes of tools are worked to and stocks kept in the tool-room, the machine men exchanging dulled tools for newly ground ones as required. It may be stated that the opinion held of curved lip tools at the Acton shops is very good. The metal is found to come away in cutting much more readily and evenly and without being sheared into short lengths. The strain on the machines is found to be considerably reduced, so that there is less vibration, and generally the conditions are better, though no claim is made for any material economy in power. In the case of small tools, cutters, drills, &c., a double system of checking is in use. A man requiring a tool signs a small receipt ticket for it. This is placed in a rack under his own number. On a peg close to this are several brass numbered checks, and one of these is taken off and placed in the tool rack for every tool taken out. It is thus possible from the receipt tickets in the rack to see at once what tools a man has out, while if a tool is absent from its place on the shelves the check gives information as to who has it in his possession. All tools are drawn into the tool room for checking purposes once a week.

A passing reference has been made above to the machine shop. This contains a large number of modern machines, most of them, however, of the lighter classes. They include a good range of all the most modern drills, lathes, grinding machines, and so on. Among those recently installed at the works is a new horizontal Plano-milling machine, with removable cross slide, by Messrs. Kendall and Gent (1920), Limited, Manchester. This machine is illustrated in Figs. 19 and 20, page 198. The most interesting feature of this is the provision for quickly resetting for a fresh cut. The machine has a table with a working surface 8 ft. long by 2 ft. 11 in. overall, the traverse being 8 ft. The distance between the front edge of the saddle and upright is 3 ft. 3 in., but as implied above, the whole cross slide and outer standard can be removed, thus making the machine available for awkward-shaped jobs. The number of spindle speeds provided is 18, ranging from 10 to 130 r.p.m., the range of feeds being 9, from 1¼ in. to 10 in. per minute. The self-acting feed traverse operates in either direction, as also does the quick-acting hand and power traverse provided for setting up. The gear box gives 9 changes of speed, and these can be combined with either fast or slow gear on the saddle. All adjustments are fitted with micrometer scales, reading to two $\frac{1}{1000}$ths of an inch. The milling saddle is provided with a locking arrangement by which the cross-slide and saddle can be locked to both vertical slides simultaneously from either side. If the cross-slide is not in use the saddle is locked independently. In the Acton shops the machine is fitted with a 23-h.p. motor. It is intended to use it primarily on gang work on axle boxes set in jigs holding six standard boxes. The quick re-setting arrangement consists of a vertical rod in a socket in the base of the main column, under the saddle. This rod, by means of necks cut on it and a collar plate can be set at various heights. In a corresponding position under the saddle is a fine-threaded screw, with a large milled head and milled lock-nut. This is screwed out or in, so as just to touch, but not to bind, a loose circular washer on the head of the rod below. After raising the saddle and running back on the quick traverse for a new cut, the cutter can be lowered without measurement or further trouble to the original height, so as to secure the same cut as before, by the feel of the circular washer between the milled head and the upright setting rod. The machine is capable of performing milling work on side, top or inside faces. Of our illustrations Fig. 19 shows the machine installed at Acton, while Fig. 20 is from a photograph of a similar machine taken in the maker's works, showing the cross-slide and outer standard removed.

In the machine shop the intention is that machines should be served by two stillages, or one double-tier stillage. Rough parts are kept on one, or on the lower shelf of the double type; finished parts are placed on the other.

For convenience we will deal next with the smith and spring shop. The smith shop does not present any features of unusual interest. It contains 17 hearths and the plant includes three pneumatic Massey hammers, one being a 5 cwt. hammer and the others 7½ cwt. hammers. A view of part of the inner row of hearths is given in Fig. 11, Plate XII; these are down draught hearths. Those against the outer wall of the shops have overhead flues. Air is supplied by a motor-driven fan, and an exhaust fan is provided for the down-draught hearths. A small device in use in the smith shop is an horizontal bending press which has been rigged up on a portable frame. It has an hydraulic hand pump and ram. The

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

Fig. 23.

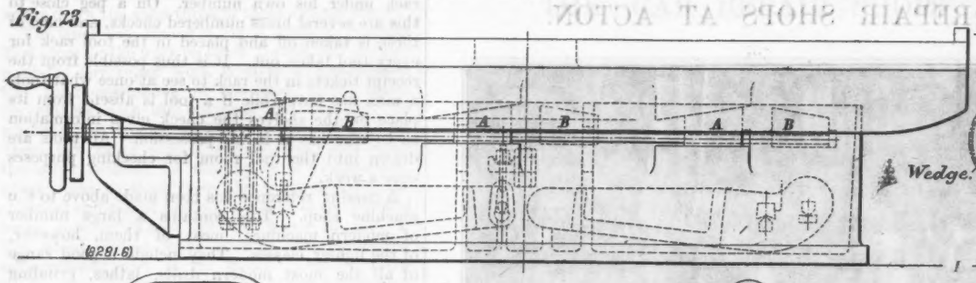


Fig. 24.

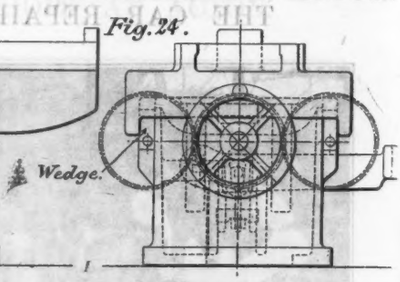


Fig. 25.

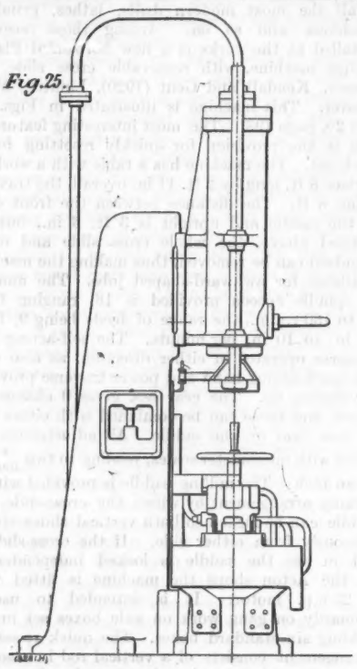


Fig. 26.

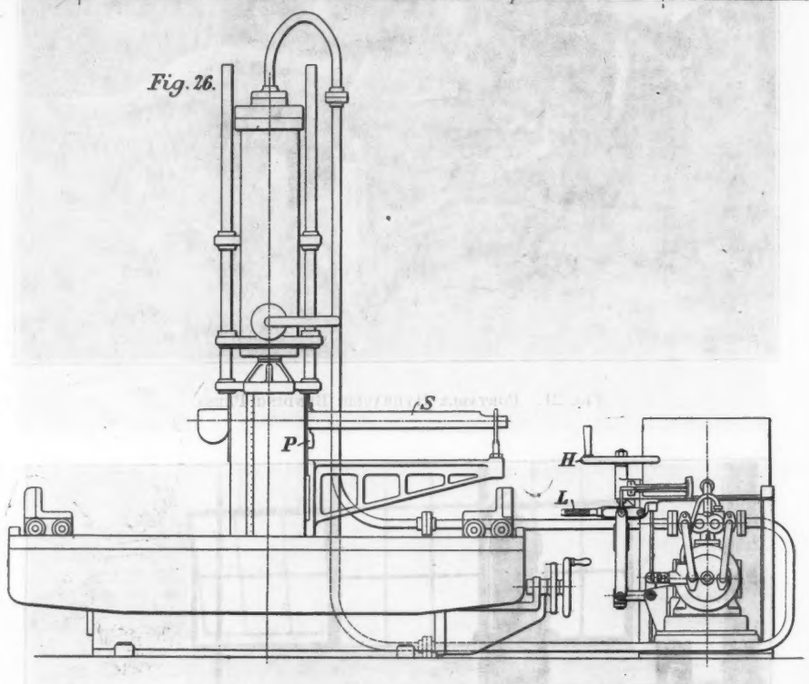
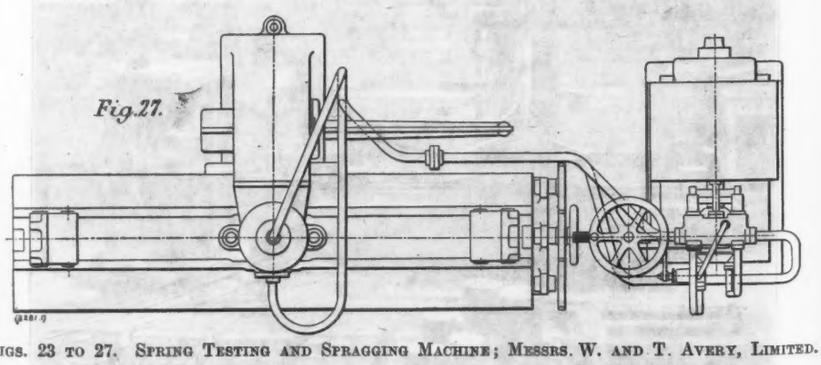


Fig. 27.



Figs. 23 to 27. Spring Testing and Spragging Machine; Messrs. W. and T. Avery, Limited.

ram is fitted with chains and lever so that it can be drawn back quickly. This is illustrated in Fig. 21. on page 199.

All springs after stripping are sent over to an Avery spring-testing and spragging machine situated close to the spring and smith's shop. A view of this machine is given in Fig. 22, on page 199, while Figs. 23 to 27, will assist in making the arrangement clear. The machine is fitted with a long table resting on knife edges in connection with the steel yard, S, fitted with a poise P, and reading up to a 10-ton load. A Hele-Shaw hydraulic gear is arranged, as shown, on the right hand, and controls the action of the ram in the vertical cylinder over the table. The ram is fitted with a crosshead and is steadied by two vertical rods operating in pairs of guides. The principle of the Hele-Shaw gear is, of course, familiar to our readers so that it is not necessary to go into details of this. Small displacements of the circular guide eccentric of the gear are obtained by means of the hand wheel H, when the loading ram is under delicate control, and any load set on the steel-yard can be obtained with ease. A file of standard prints giving loads and deflections for all springs is kept at the desk and all springs coming into the shop are at once tested. If they fail under test they are sent over to the spring and smith shop to be set.

When the machine is used for spragging, the table is lifted by wedges A and B, clear of the knife-edges and, by taking out a pin in the screw gear, this is rendered inoperative, and the ram can be given large movements up and down following the movement of the hand lever L. This effects a large displacement of the guide ring on either side of the neutral position and consequently a rapid movement of the loading ram. The system of wedges and the screws and hand wheel for working them are shown in Figs. 23 and 24. The Hele-Shaw pump is driven by an electric motor.

A twin furnace is provided for spring work, coal fired. One compartment of this is maintained at 1,200 deg. C. for plate setting, while the other is kept at a temperature of 400 deg. C. for tempering. Each compartment is double fronted so that gangs can work on either side of it. Forming part of the smith shop is an electric welding section employed for the building up of worn parts. Three single operator units are in use here.

Although fires are used in the smith shop electricity has been adopted for much of the heating work about the shops. Thus, as will be described later, the tyre-heating furnaces are electrical. In some directions the spasmodic nature of the work has resulted in electric heating giving excellent and economical service. For instance, in the truck shop, where riveting is necessary in varying amounts, electric rivet heaters have been introduced. These, for such work, have manifest advantages. They can be got going without any delay, even if only one or two rivets have to be dealt with. No boy is required to tend the fire. No smoke or dirt is introduced into the shop and power is cut off as soon as the work is over. With the same ends in view a very handy pipe heater has been developed for use in the pipe section for brake and duct work. This we illustrate in Fig. 28. The machine has two clamping heads between which the pipe is clamped to complete the secondary circuit of the unit. These are adjustable so that the distance apart may be varied. Both of these heads swivel

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

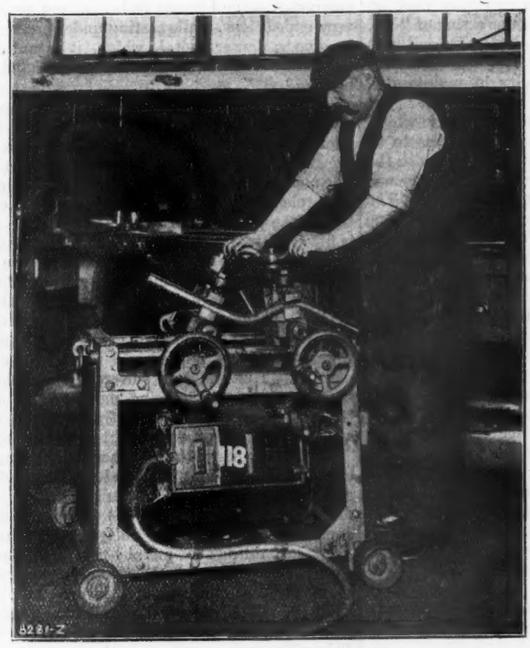


FIG. 28. ELECTRIC PIPE HEATER.

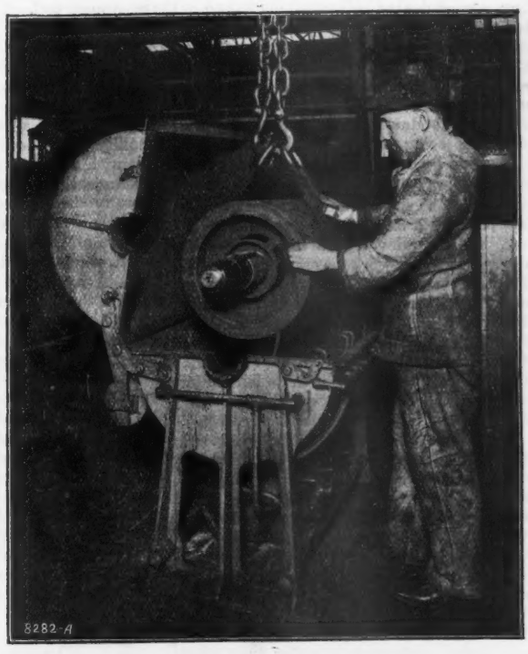


FIG. 29. ARMATURE CLEANING MACHINE.

FIG. 30. MOTOR ASSEMBLING SECTION.

on an horizontal axis, and are also arranged so that the clamps swivel on a vertical axis. In this way the machine is available for pipes having compound bends of all kinds. In addition to heating for bending, a good deal of bell-mouthing has to be done. In order to heat the pipe ends for this work, one of the heads is fitted with a copper cone and the pipe is held in the other clamp. The cone is then forced up against the open end of the pipe and considerable pressure exerted to maintain a good contact. The device is very effective, the time of heating being much less than with an ordinary small fire, with, again, the advantages of instant readiness for use, no stand-by losses, &c.

The sections of the shops dealing with electrical equipment, brake gear and compressors hardly call for remark, but that devoted to motors requires rather more notice. All work on motors is done in a special section where these parts are received on platforms from the stripping bay. They are placed under a 3-ton 20-ft. radius jib crane and dismantled. On removal from the cases the armatures are first transported to a cleaning plant shown in Fig. 12, Plate XIII, where they are placed in an horizontal cylindrical case with bearings at each end to take the shaft. The upper half of this case is hinged, and can be thrown back while the armature is put in position. Inside the case on the horizontal diameter is arranged, as shown in Fig. 29, a series of compressed air nozzles fitted on swivelling arms so that each can be brought directly opposite one of the rows of ducts in the armature. At the bottom of the case is an opening leading to a duct passing under the floor to an exhausting fan driven by a 20-h.p. motor. This fan draws the dust-laden air out of the closed casing, in which the armature is slowly revolved, and before delivering it to the atmosphere passes it through a water trap filter where the dirt is left behind. The tank of this trap is fitted with a cleaning door on a level with its bottom, and the effectiveness of the treatment is proved by the large amount of dirt which is removed from the trap.

After cleaning, an armature is passed by overhead telpher on to the binding machine where, however, only small repairs are done. No heavy work of this kind is at present undertaken at Acton, most of the re-winding of both armatures and field coils being still done at Golders Green, though ultimately it will be removed to the new works. From the binding machine the armature is passed on to the Dean, Smith and Grace lathe shown in Fig. 13, Plate XIII, for commutator turning and the turning up of journals, pinion fit, &c. At the end of this machine stands a keyway shaper to which the armature can be passed if the pinion keyway requires attention. From these machines the armature is taken, still by telpher, to a light shaper for trimming out the mica of the commutators. As this leaves the edges of the copper commutator strips rough, the armature is finally passed on to the stands shown in Fig. 15, Plate XIII, where they are finished by hand. Subsequently they are spray-painted with insulating varnish, by means of a small portable Aerostat plant, and are then stacked in a rack trolley in lots of seven, and passed into the drying stove, as illustrated in Fig. 14. Here they remain for twelve hours, and on the completion of the drying-out process are drawn out on the other side where they come under the assembling crane which is illustrated in Fig. 30.

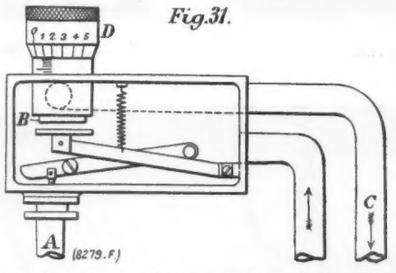
The cases concurrently receive attention. At present these are cleaned by hand, but a machine, to be seen in Fig. 12, is in process of development for treating them on lines somewhat similar to those adopted for the armatures. In this instance the field case is up-ended and a series of suspended compressed air nozzles are worked automatically up and down inside. This gear is electrically driven and includes a reversing arrangement so that when the nozzles reach the highest or lowest point they will commence to re-traverse the case in the opposite direction. The field coil case will be enclosed in a box from which the air will be exhausted by fan as in the case of the armature cleaning installation.

As in the case of the armatures, comparatively light work only is done on the field coils at Acton. A field coil winder is provided, but is utilised for small jobs only, the Golders Green plant being at present relied upon for winding, &c. Much of the work on the cases at Acton consists in replacing the pattern of field coil used till recently with a plain tape wound coil. The pattern generally used up till now has included a spool forming a ring of "U" section, within the rims of which the coil was wound. The use of the spool has now been discontinued owing to the difficulty in maintaining good insulation between it and the coil.

After cleaning, all bearings are sent to the white-metalling shop for treatment. The patterns to be dealt with here are very numerous, though with the standardisation of axles and boxes the types will naturally be reduced in course of time. The bearings are in some cases plain, with a radius at one end. In other cases they are formed with an end cap on which the side thrust on the axle is taken. The patterns include bearings with steel shells fitted inside with phosphor bronze strips, which form a key for the white metal and, further, in the case of melting out, a temporary bearing for the journal until the car can be cut out.

Down the centre of this shop runs a two-tier bench divided into sections. On the lower shelf are placed all the old bearings as they come in, in their correct section. The upper stage is reserved for finished bearings, and at the end nearest the door is always kept a stillage ready for loading up with the finished parts. The bulk of the work in this shop is done with plant which was designed by the Monometer Manufacturing Company (1918), Limited, of London, and manufactured at the works of Messrs. Vickers, Limited, Barrow-in-Furness. The chief unit of this consists in a furnace for melting the metal out of old brasses, and a pressure

Fig. 31.



die-casting plant which serves the majority of the types of bearings in use. A general view of this plant is given in Fig. 32, page 208, the pressure-casting plant being in the foreground and the bearing heating furnace in the back ground. The latter is a continuous furnace, maintained, by an automatic Monometer temperature regulator, at a temperature of 350 deg. C. The floor of the furnace is sloped and the bearings are placed on an endless chain conveyor, operated by a crank handle, as will be evident from Fig. 33. The feeding end of the furnace, which is long enough to take 14 bearings at a time, is shown in Fig. 34, both ends being fitted with balanced doors. The slope is such that metal will run out of the bearings as it melts and is drained into a pot, or into a mould, placed under the spout at the side.

The shells on emerging from the furnace are quickly passed on to the die-casting machine, where they are pushed against a stop and picked up by the grip shown in Fig. 35. This little device catches hold of the hot shell between two fixed curved claws and a movable finger, worked by the lower or right-hand lever. The left-hand lever is fixed to the frame. The shell is gripped and the carriage tilted and moved forward on a pair of wheels running in grooves, and is deposited on the die against locating stops. On the left hand of the die is a swivelling clamping piece, and this is swung round, so that a distance piece stands immediately under the vertical screw of the top frame. This screw is then lowered, the end block being screwed up by the small hand-wheel at the base of the frame. The large star hand-wheel at the side of the machine works the ram, which forces the molten metal contained in a pot in the base into the die. To remove the bearing, after casting, the same grip is used as before. The metal is maintained at 360 deg. C., again automatically by means of a Monometer regulator, so that the operator has no need to concern himself with this point, and risk of overheating the metal is avoided. The automatic temperature regulators, moreover, save a considerable amount of gas and the whole lay-out renders working very expeditious, while casting under pressure tends to give a denser metal, which, it is anticipated, will give a higher life than the usual hand-poured bearing.

For bearings which are too large to be handled by this machine, such as suspension bearings for motors, a large white-metal pot is provided. This is also by the Monometer Company. It is illustrated in Fig. 36. The metal in this furnace is always in a non-oxidising atmosphere, the waste gases being passed over the top of the pot through branch pipes. The furnace is fitted with a mixing device consisting of a scoop-shaped paddle worked by a handle on the top of the dome cover. The metal is drawn off from the bottom by means of a valve worked by the large hand-wheel overhead. Absolutely clean metal is thus assured. In the view given two bearings are shown, one being poured and the other ready for pouring. The metal is run round polished steel mandrels, the whole being mounted on a small trolley on rails, passed in front of the pouring spout, and then run on out of the way to cool.

The Monometer automatic heat regulator consists of a thermostat controlled valve. Inserted in the gas pipe is a small rectangular box (shown diagrammatically in Fig. 31) which is mounted over the furnace. From this a thermostat tube A passes into the metal pot or furnace, as the case may be, the thermostatic element being connected by multiplying levers with a disc valve B, which is moved towards, or away from, its seat on any change of temperature occurring. This allows more or less gas to leave by the exit pipe C to the burners, as required. The valve seat is fitted with an external knurled-headed micrometer screw D, and is thus adjustable, and may be set to any position found to give the required normal temperature. Any subsequent fluctuations are taken care of by the thermostat regulation.

There is, in addition to the large bearings which are not handled on the die-casting machine, a certain amount of white-metalling work to be done on a scale for which it would not be worth while to provide expensive dies, especially in view of the fact that in course of time, with increased standardisation, some of this will be eliminated. For this class of work benches are provided down one side of the shop, where the work is carried out in the ordinary way by hand.

We propose to reserve a description of the wheel and tyre-section of the works for our next issue.

(To be continued.)

THE INSTITUTION OF MECHANICAL ENGINEERS.

ON Friday last, the 8th inst., an extra general meeting of the Institution of Mechanical Engineers was held at which Sir John Dewrance, the President, occupied the chair.

REPAIR AND UPKEEP OF PNEUMATIC TOOLS.

The subject for discussion was "The Repair and Upkeep of Pneumatic Tools," a paper on this subject being contributed by Mr. R. W. Wilson, of Newcastle-on-Tyne. This paper we reprint in full on page 219 of the present issue.

Mr. Frank Hills opened the discussion. He demurred to the author's use of the term "rough" in the paper, in connection with pneumatic tools, and thought the word "rugged" would be preferable. Leaks, of course, should be obviated. A notable feature which developed in tests he had made was the leakage over the throttle valve. This was not noticeable when the tool was lying down, nor, on account of the noise, when the trigger was pressed. It would be a revelation to most users if they tried tools with all the tools plugged, pressing the trigger and using an air meter. He considered that a good fitter was quite a suitable man to look after the tools. With regard to the drop of pressure being a cause of inefficiency, he believed this to be often attributable to the use of self-closing couplings

in order to save the men going to the nearest air cock. In the case of a ½ in. coupling in a ½ in. hose pipe, an attempt to include a special self-closing connection would practically close the hole.

With regard to measurements for rivet hammers it was well to take air consumption per rivet. In the case of chipping hammers, the basis might be the amount of metal removed. Little was said about drilling machines in the paper. It would be interesting to know what test the author considered the best test for drills. He (Mr. Hills) had found the plain brake test excellent in relation to research work. With the brake horse-power averaging about 1½, he had tested a machine at one period and again six months later, and the results showed a difference of only about 1/100 h.p. Of course, drilling machines were always tested by the drilling test before leaving the works of a firm. He thought that the goodness or badness of a hammer should be estimated by the number of blows per minute. He had used two identical hammers on tests, one giving a very large number and the other a much smaller number, and found the latter to give the best results. The works reports on the two tools was at first in favour of the fast one, but after three months' working this report was reversed. It had been represented to him that a hammer of a particular size which worked admirably at 100 lb. pressure fell off rapidly at 70 lb., and he had therefore made a number of tests with various hammers to get them to work with proper efficiency as the pressure dropped. He felt that the falling off of efficiency was entirely due to the speed of the piston rather than its stroke. For 1 in. or 1⅛ in. rivets, it was found that a piston of about 88 mm. in length was best. Some of the men were keen on reducing the length of the piston, grinding it down themselves. The result was a more rapid blow of the hammer and greater comfort in holding, but actually, of course, at reduced power. In chipping, when working too fast, much power was absorbed in heating up the chisel and also the chip.

Mr. Hornbuckle thought the method of making the workmen responsible for the care of the tools an excellent one. With regard to power costs, he thought the author's figure of 20*s.* 1*d.* for 100,000 cub. ft. of free air compressed to 100 lb. per sq. in. pressure was very low; he would be glad if that could be checked. Would the author say whether the test took into consideration any air-governing arrangement? Could the author give figures of the cost of maintaining flexible hose and connections? In most systems air leakage was considerable. Unless the connections from the main were kept in very good condition, leakage from a large number of points often formed a high percentage of the total air compressed. In testing drilling machines, he had found it an easy method to have a small electrical machine geared to a spindle with a standard Morse taper. A machine, after repair, was slipped on to the spindle and started up. An ammeter reading showed at once the practical efficiency of the machine. Drilling, however, was the real test of a drilling machine, and unless the speed of the machine was proportioned to the diameter of the drill to be used, no test would really give a true measure of the efficiency of the drilling machine.

Mr. S. E. Thornton thought the author had not emphasised sufficiently the extravagance of leaky joints. Drills were manufactured for the minimum consumption of air, and it was disheartening to see air going out at every pipe joint. It would be very useful to have some standard test for hammers if it could possibly be done, but he thought the human element prevented this. Mr. Amos read what was probably the last paper on the subject twenty-four years ago. It was then stated that a 1 in. drill would go through 2 in. of mild steel in two or three minutes. It was now possible to do as much as 100 per cent. better than that. The economy now must be very considerable.

Mr. W. G. Corner said pneumatic tools were often abused because it was forgotten that they were the means of putting horse-power into the men's hands. The pneumatic drill, weighing about 40 lb., contained a motor capable of developing 2 h.p., and naturally more attention was needed than in the case of a ratchet drill. With the pneumatic machine a workman's output was increased four or five times. In the past makers had recommended immersion of the tools in paraffin or similar oils. Usually the only fluid in a hammer was water. Would the suggested immersion in paraffin oil remove the water or other foreign matter? He thought immersion in paraffin allowed water to get on to particular parts or passages during, say, the week-end, with consequent erosion. The paraffin bath was, in his view, responsible for much trouble. If hammers could be taken to pieces more easily, the interior would be better looked after. He considered for efficient use, air pressure should approach 90 lb. to 100 lb., and the provision of dry air by means of a suitable receiver and packing arrangements was exceedingly important. The receiver lessened the rate of flow of the air and cooled it, giving it a chance to deposit its moisture in the receiver instead of in the pipe lines. With regard to leakage, some firms employed a man to do nothing but look after leaks, and probably they derived a good return from that expenditure. Much air was wasted in using an unsuitable size of drill, particularly one larger than necessary. A drill for a 1¼ in. hole run all day long on a ½ in. hole would be revolving at a terrific rate, wasting air, probably heating up the lubricant, with resulting damage to working parts. Some form of governor was needed which would do away with racing under light load, and especially under no load at all.

Mr. William Reavell said that since Mr. Amos' paper much had been done to improve pneumatic tools and their performance. It would be an advantage if the Institution could get together a symposium of papers on the use of compressed air with tools. There was, moreover, the use of compressed air in various ways in foundries. With regard to the table of pneumatic details given in the paper, this would be more useful if the figures for cost of upkeep could be reduced to give, say, the cost per tool per hour worked or per 100 hours worked. The total cost per tool given represented 12 months' working, with no indication of the number of hours in the year that the tool had been at work. The table showed a remarkable difference per tool per year. A column showing cost per tool for an equal number of hours would be informative.

Further, the pipe lines and fittings were badly looked after. If those responsible for pneumatic tools would learn the great importance of avoiding air leakage, of having adequately dimensioned proportions and suitable flexible hoses, the over-all efficiency of the tools would be greatly enhanced. At Ipswich, it was the practice once a week, during a meal hour, when the shops were silent, to go over all the pipe ranges and listen for leaks, however minute. The places of leakage were carefully marked and at once repaired. With regard to drop of pressure, due to too small pipes or leaky hose connections, the detrimental effect was amazing. Recently, in a certain district, a compressor was installed for driving a ¾ in. riveter. A high tower was being riveted, and as it progressed upwards the work done by the riveters grew worse and worse until the complaint was made that the 90 lb. air pressure at the compressor had become 45 lb. at the work. The fault was with the hose, which was much too small. As the work proceeded fresh lengths were attached, without any increase in diameter, while no trouble was taken about the joints. A general tendency existed to buy an inferior quality of hose and to use a hose of too small a diameter. With regard to water troubles, theoretically, of course, hot-air compressors should not be used, but buyers lacked discrimination, and cost often prohibited ideal conditions. However, a user paid a surprising extra amount in horse-power per annum simply because he put down an inefficient compressor. A few days since he had compared two machines of identical size, but of differing price, and the actual horse-power supplied by the motor to each compressor per 100 cub. ft. of air compressed was in one case 25 per cent. higher than in the other. Figures showed that in three months of average use the difference in cost of current used would have paid for the difference in the cost of these compressors.

Mr. Reavell then proceeded to describe the type of machine they used for ascertaining the efficiency of pneumatic picks for coal mining. This consisted of a stand in which a rod would move up and down, guided at its upper end by an enlarged part or collar. Beneath this was a compression spring. The blow of the hammer was transmitted to the vertical rod. The recording mechanism consisted of a pin attached to the moving part, in front of which a band of paper was drawn by suitable mechanism. The record gave a line interrupted by a number of Vees. The deeper the Vees, and the narrower they were across the top, the more effective the tool. Figs. 6 and 7 of the paper brought up the question of makers' rating. The diagrams would have been of greater value if information had been given based on the same number of ft-lbs. of energy. It was gratifying to notice that the best performance was that of the English hammer.

Mr. W. H. Patchell remarked that several years ago the late Mr. Bowen Cooke had sent the Institution a brief sketch on the subject, and the attempt had been made to get a larger paper to read with Mr. Cooke's, but without success, and a symposium had then been tried, but nothing came of that either. Mr. Wilson's paper would bear considerable analysis, and he hoped users of pneumatic tools would take heart, and see real value in their records and in exchanging records with each other. A friend of his from China had told him that the great drawback to the use of pneumatic tools in China was their heavy weight. Weights ranged up to 40 lb. In the East the men wanted lighter tools. His friend was in Manchuria, where the men were strong, but in Southern China, and in other warm countries, heavy tools were not appreciated. What was the meaning of "rated capacity" in connection with Fig. 7? Was it "rated" in work done, cubic feet of air used, or in what? There should, he thought, be some sort of standard.

Mr. N. R. Redfern said that he was greatly interested, as a potential user of pneumatic tools, in the Tropics. His firm had seriously considered the installation of a pneumatic plant in a shipyard in Africa. On going into the matter they found two other firms had put in such plants, which had never been seriously worked because of the trouble natives had in handling heavy tools. If his firm could be confident of getting a plant which could be satisfactorily worked, they would probably, when financial conditions were easier, instal one. He thought more propaganda work might be done, and mentioned the American journal, *Compressed Air*, as an example of means which might be taken to popularise this form of power.

The President, in calling on the author to reply, remarked that at the annual general meeting a short time would be devoted to the further discussion of the paper.

Mr. R. W. Wilson, in reply, said he was quite prepared to accept Mr. Hills' suggested word "rugged" in place of "rough," as applied to a pneumatic tool. He agreed that self-closing couplings throttled the air, and were often the occasion of a drop in the efficiency in pneumatic tools. They were, however, useful in saving air, although when the tools remained fixed for a considerable time, they were not of such great service. Leaks, as Mr. Hornbuckle had remarked, were undoubtedly expensive. It was seldom realised by engineers that compressed air was nearly as expensive as gas. Few people appreciated that the noise heard with an escape of air was so expensive. It happened sometimes that one-third of the air compressed was lost in leaks. Referring to the remarks about natives, he thought the dislike of the native to use a pneumatic tool was partly due to timidity. Even in his own shops the men had sometimes been afraid to use pneumatic tools. However, natives were largely employed on the Rand in work requiring pneumatic tools, chiefly rock drills. It might be pointed out that on the Rand the tendency was to use heavier and heavier tools, and that there they were getting two natives to hold one tool. In America the application of compressed air was far in advance of its use in this country, but there was no reason why it should not be used here to as great an extent as in the United States.

After a vote of thanks, the proceedings were closed with the announcement of an informal meeting to be held at 7 o'clock to-day, the subject for discussion being "Internal-Combustion Locomotives," introduced by Mr. Alan E. L. Chorlton, C.B.E., Member of Council.

THE SCATTERING OF X-RAYS.

SIR WILLIAM BRAGG'S Royal Institution discourse of last Friday—an alteration in the programme had become necessary—did not deal with the aspect of X-ray research, on which he had opened a series of lectures on the previous day, but concerned the old controversy between the corpuscular and undulatory theories of light. The nineteenth century, Sir William said, had considered the controversy settled in favour of the wave theory; the discovery of radioactivity and various radiations had raised it again. Both Newton and Huygens had supported their theories with great ingenuity, but had been unfortunate in their mutual criticisms. Newton believed that the source of light emitted corpuscles which were received by the eye, but he also believed that waves followed or accompanied the corpuscles, and he developed his hypothesis of "fits of easy reflection and of easy refraction"—matters upon which Professor H. A. Lorentz had dwelt in his discourse on radiations,*—whilst maintaining that light could, on the wave theory, not travel in straight lines and could not cast sharp shadows. Huygens, on the other hand, objected that light corpuscles could not pass through one another without colliding and falling out, and that Roemer's determination of the velocity of light—in the year 1676, from observations of the ocultations of the moons of Jupiter—demanded impossible velocities for the corpuscles.

In an X-ray bulb, Sir William continued, the cathode sent a stream of electrons against the target, which then emitted invisible X-rays; the rays striking the photographic plate or any obstacle again emitted electrons, and so we had electrons, waves and electrons in succession. Apart from the characteristic radiations, the secondary electrons left the plate or obstacle, no matter of what nature, probably with much the energy and velocity of the primary electrons, and to speed the former up we had to speed up the latter. If we imagined the bulb to be enormously magnified, with a cathode as big as the Moon, and the Earth as plate (the distance would roughly be proportional to the usual experimental distances), one electron might hit London and the next the Indian Ocean. How did those electrons get their energy? It had been suggested that the electron merely acted as trigger releasing the atomic energy of the molecule struck; but that was quantitatively not satisfactory, and one could not understand, then, why the energy should be concentrated in the forward direction, as it was.

It had, therefore, been proposed that light travelled in "quanta" of energy bundles, and that the quantum striking an electron would rebound with all or part of the energy, preferably in the forward direction. Such a view involved a peculiar interweaving of the two theories. In his work on X-rays and crystal structures, Sir William said that he accepted the wave theory; in other work corpuscles were concerned, and he might thus be said to work on one theory on one day in one part of his laboratory and on the other theory on another day in another part. The recent work of A. H. Compton, of St. Louis, now indicated a suggestive similarity between fluorescence of light and X-ray phenomenon.

Before proceeding to this point, Sir William demonstrated by a simple experiment the interaction between light and electrons. A Wimshurst electric machine was fitted with a large disc electrode of zinc opposite a small brass-sphere electrode. The machine was so worked that the zinc disc was the negative electrode. Sparks passed at regular intervals. But when a magnesium flame (a burning wire) was brought up to the gap, the sparks stopped; when a stout glass plate was interposed between the flame and the gap, the sparking recommenced. A discharge would take place when the charge, accumulated upon the electrodes, broke down the air gap; the current was carried by the negative electrodes. When, however, the ultraviolet magnesium rays fell upon the zinc, they liberated so many electrons from it, that the discharge set in at once, before the disruptive charge could take place; the interposition of the glass cut off the ultraviolet rays, so that the charge could again accumulate and sparking could recommence. As regards fluorescence, it had long been known that, when ordinary light fell upon a fluorescent substance, that substance emitted light of a lower frequency or of larger wave-length. That was demonstrated by sending a beam of spectrum light (through a prism) into a solution of eosin; the red and yellow passed through the solution, apparently without doing anything; the rest of the rays caused the eosin to fluoresce green.

The nuclear condensation experiments of C. T. R. Wilson, Sir William continued, had made visible the paths of X-rays and other rays and of the electrons which they liberated from moist rarefied air. In Fig. 1 a cylindrical X-ray beam, 0·5 mm. in diam., had been sent through the condensation chamber. The photograph showed a dense agglomeration of nuclei and, further out, some isolated points and paths due to scattered electrons. In Fig. 2 a very thin foil of copper, attached to a copper wire, was interposed in the beam; there was a dark space about the foil, probably due to heat disturbances, but outside that the electrons were more crowded, whilst weaker in the space beyond. The path of swift electrons would be straight for many centimetres, but tortuous when they lost energy by collisions; such tortuous paths were seen in Fig. 3. For the experiment, illustrated in Fig. 4, the rays had been filtered through 9·2 mm. of aluminium before entering the chamber. Only one electron was seen to come out of the copper plate. That electron had been ejected from the K-level of a copper atom; stopped by collision with an oxygen or nitrogen molecule, it seemed to have liberated a secondary electron, which, going on with the rest of its quantum, had started the second short path marked.

When now ordinary light was scattered, there was no change of colour or of wave-lengths; the sky appeared blue because the fine dust particles scattered blue rays more than other rays. But in Compton's experiments on the scattering of X-rays there was indication of emission of rays of larger wave lengths, somewhat as in fluorescence. Compton's experiments had been made because the formulæ of Barkla and J. J. Thomson, based upon electrodynamic considerations, had proved insufficient for X-rays of great penetration; the scattered energy seemed to be much smaller than Thomson's value, so that this energy would not be independent of the wave-length used; the scattered energy was, moreover, found to be concentrated on the emergent side. Compton compared the primary spectrum of K-rays from molybdenum with the spectrum obtained when the rays were reflected by graphite. He observed a displacement of the lines towards the region of longer waves. Assuming that when an X-ray quantum was scattered, all its energy and momentum would be spent upon some particular electron which in its turn scattered the rays in some definite direction, he suggested that the longer waves were emitted by loosely bound electrons free to recoil, the energy in the scattered quantum being smaller than the primary quantum by the energy of recoil of the scattering electrons.

These experiments had been confirmed by P. A. Ross, but they were questioned by Duane. Within the last few days Dr. A. Müller, working in the Davy-Faraday Laboratory, had, after incipient

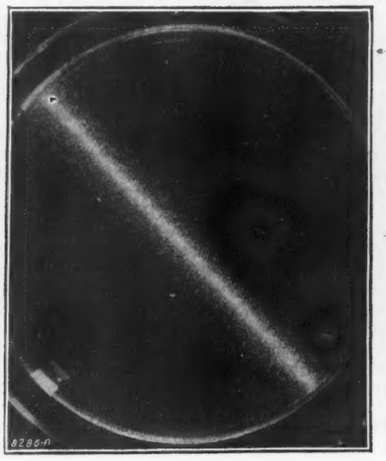


FIG. 1.

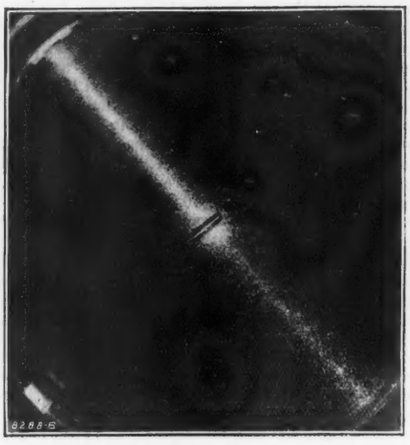


FIG. 2.

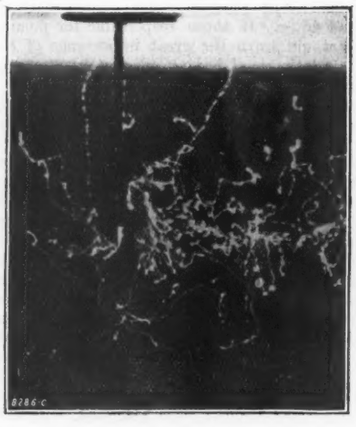


FIG. 3.

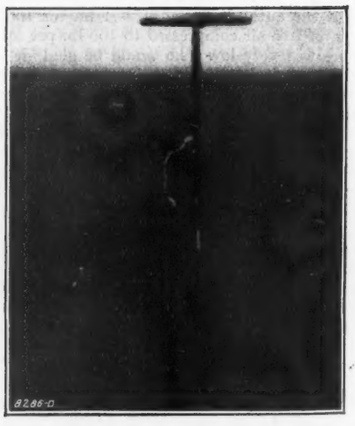


FIG. 4.

* See ENGINEERING, June 8, 1923, page 118.

THE VICTAULIC SYSTEM OF PIPE JOINTING.

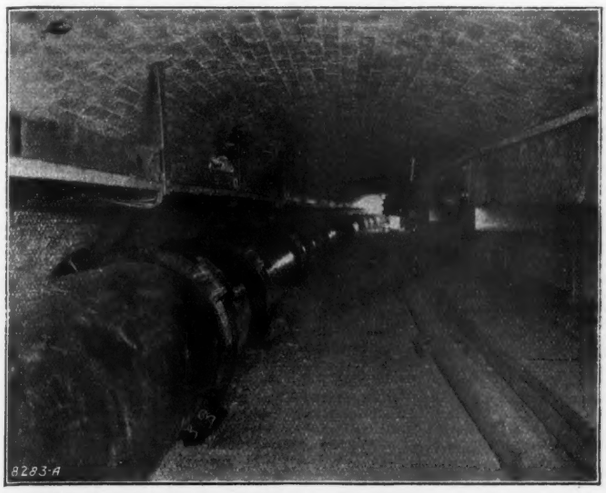
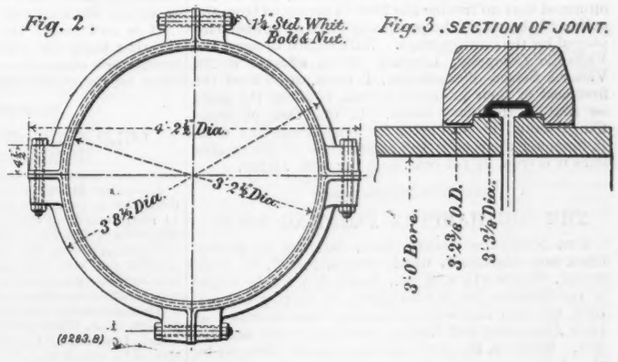
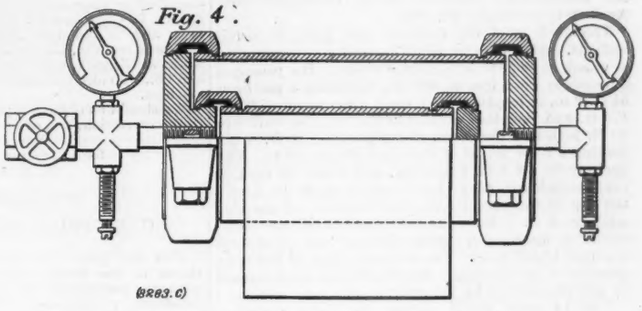


FIG. 1.





failures, confirmed the experiments, using targets of various metals and blocks of paraffin as reflectors. The slides exhibited showed the displaced lines quite distinct, though very faint, in spite of exposures of many hours. Sir William accepted the confirmation, but remained doubtful as to its interpretation. Yet it might be, he concluded, that Newton was nearly right after all in assuming that both waves and corpuscles were involved in the effects of light.

VICTAULIC SYSTEM OF PIPE JOINTING.

SINCE the form of pipe joint, now known as the Victaulic joint, was first put on the market over four years ago, its design has been modified in some respects, mainly for the purposes of reducing manufacturing costs and increasing the number of possible applications. Examples of these joints have been illustrated and described in our columns on previous occasions, and if these are consulted* it will be seen that the fundamental principle upon which the joint depends for its effectiveness has remained unaltered. The joint, it will be remembered, is formed by a rubber ring of C-section, the lips of which are forced into close contact with the adjacent ends of the pipes to be connected by the pressure of the fluid in the pipes. To hold the rubber ring in position, and to enable it to withstand the pressure of the fluid, it is enclosed in a metal ring, or housing, which is arranged so as to prevent the ends of the pipe from being drawn apart while still permitting a certain amount of flexibility in the joint.

This property of flexibility is of considerable utility in many practical applications, since it obviates all difficulties due to thermal expansion and contraction and allows the position of a pipe line to be adjusted within certain limits without affecting the tightness of the joints. It also allows a pipe line composed of straight lengths to be laid with a considerable degree of curvature, although the amount of curvature possible in any given case naturally depends upon the diameter of the pipe and the form of the joint employed. In any case, if a length of piping with Victaulic joints should prove defective under test, or should be broken or damaged under working conditions, it can be replaced with much less trouble and expense than would be involved in the case of a similar pipe line with joints of the spigot and socket type. Another feature of Victaulic joints which often proves useful in practice is that they can be made with great rapidity and in such confined spaces that the room available for working would be insufficient for running and caulking spigot and socket joints.

These last-mentioned considerations, we believe, were largely responsible for the decision of the engineers of the Metropolitan Water Board to use Victaulic joints for the 36-in. water main which has just been laid in an existing tunnel under Southwark Street between Red Cross Street and Borough High Street. The section to which we are referring forms part of a main connected at one end to a 36-in. main in Westminster Bridge Road bringing water from Hampton, and at the other end to a 24-in. main now being laid in the Tower Subway under the Thames to convey the water to districts north of the river. The greater part of the main has been laid underground with spigot and socket joints of the ordinary pattern, but for the section, about 200 yds. in length, laid in the tunnel above referred to, Victaulic joints were adopted. These joints are also being used for the section laid in the Tower Subway, the pipe in this case being of steel in 24-ft. lengths. A view of the tunnel with the 36-in. main in position is given in Fig. 1 on this page, while the design of one of the joints is illustrated in Figs. 2 and 3. The tunnel, it should be explained, is of brick construction, of semi-circular section, and measures 6 ft. in radius. As shown in Fig. 1, it accommodates a 6-in. hydraulic power main and a large number of Post Office telephone and electric power cables. Moreover, a large brickwork sewer is situated immediately below the centre line of the tunnel, and in these circumstances it was necessary to place the new water main quite close to the side wall of the tunnel. The difficulty of running and caulking spigot and socket joints under these conditions will be obvious. Also, it will be noticed from Fig. 1 that the tunnel is curved to an extent which would have necessitated the use of special pipes had spigot and socket joints been employed. As actually laid with Victaulic joints, however, the pipe is composed entirely of straight lengths, mostly 12 ft. long, although a few 6 ft. lengths have been introduced to avoid buttresses. In all, 58 joints were used in the 200-yd. run of the pipe.

An elevation of one of the housings is given in Fig. 2, while a section through the joint itself is reproduced in Fig. 3. From the latter it will be seen that the pipes, which are of cast iron and were supplied by the Stanton Ironworks, are formed with a small solid collar at each end, on the machined edges of which the rubber jointing ring bears. The housings which enclose and support the jointing rings are formed with a recess in the inner face into which the collars on the pipes fit as shown in Fig. 3. The width of the recess is sufficient to allow a movement of $\frac{1}{8}$ in. between the ends of the pipes, but further movement is prevented by the vertical faces of the collars coming into contact with the edges of the recess in the housing. A tight joint is secured irrespective of the pressure in the pipe, since the higher the hydraulic pressure becomes, the greater is the pressure between the in-turned lips of the jointing ring on the edges of the collars on the pipes. The tightness of the joint is also unaffected by the movement of the pipe within the prescribed limits while under pressure, the principle being, of course, exactly similar to that employed in the hydraulic U-leather.

The housings are of cast semi-steel, and, as shown in Fig. 2, they are made in four segments joined together by $1\frac{1}{4}$ in. Whitworth bolts passing through lugs cast on the ends of each segment. In making a joint, after the pipe sections have been placed in position with the rubber jointing ring over the adjacent ends, the segments of the housing are bolted together one at a time and slipped round the pipe so that the last segment can be inserted from the same working position as that from which the first was applied. It is only necessary, therefore, to have access to one side of the pipe line when making the joints, which was a distinct advantage in the particular application we are now dealing with. Sufficient earth must, of course, be removed from under the ends of the pipe sections to enable the housing to pass round freely. We understand that the average time occupied in making a joint was about 20 minutes, while that required for making a spigot and socket joint on a pipe of the size in question would be from $2\frac{1}{2}$ to 3 hours; about 60 lb. of lead and 5 lb. of yarn would also be required for each joint of the spigot and socket type. The Victaulic joints have now all been tested at a pressure of 170 lb. per sq. in. and found perfectly tight, although the normal working pressure on the main will be 90 lb. per sq. in.

It will be obvious from the above description of the design and construction of the joints that they can be designed to resist the highest pressures employed in practical engineering work, but their suitability for low working pressures or vacua are less evident. Experience has shown, however, that the joints give perfectly satisfactory service under vacua, and to demonstrate this, the apparatus illustrated in Fig. 4 has been devised. As will be seen, an outer cylinder composed of a short length of piping and two end plates, connected by Victaulic joints, encloses a second cylinder similarly fitted at one end on to a boss on one of the end plates, the other end of the inner cylinder being free. Air at a pressure of two atmospheres is first admitted to both cylinders through the valves shown at the bottoms of the screwed connections at each end, the pressure being indicated by gauges, one of which is in communication with the outer cylinder and the other with the inner cylinder. The air from the inner cylinder is then allowed to escape rapidly by opening the cock shown on the left of the illustration, so that the pressure in the outer cylinder exceeds that in the inner cylinder by one atmosphere; the effect on the joints is thus the same as would be experienced by the sudden application of a complete vacuum to the inner cylinder. Any escape of air through the joints from the outer cylinder to the inner cylinder would, of course, be accompanied by a fall of pressure in the former which would be shown by the gauge, and the fact that no movement of the gauge takes place is an indication that the joints remain tight under these conditions. Actually the test has been carried out at pressures of 70 lb. per sq. in. with exactly similar results.

Victaulic joints have now been employed for pipe

* See vol. cviii page 479; vol. cxii, page 375; and vol. cxvi, page 293.

lines carrying compressed air, gas, water and many other fluids, including oil, although we believe it has not so far been used for steam. Some 50 miles of oil pipe line have now been laid with Victaulic joints, and we are informed that no trouble has been experienced from the action of the oil on the particular class of rubber employed for the jointing rings. With regard to costs, the Victaulic Company, Limited, whose address is 28, Victoria Street, Westminster, London, state that the first cost of their joints, in general, is about the same as that of ordinary joints. In the case of loose-flange joints, for example, for pipes exceeding 6 in. in diameter the cost is the same, while in the smaller sizes it is from 2½ per cent. to 5 per cent. higher.

THE SOUTHAMPTON FLOATING DOCK.

The 60,000-ton floating dock, designed by Messrs. Clark and Standfield, which Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited, have in course of construction for Southampton, is nearing completion, the two last sections having been launched at their Armstrong and Walker yards on the 6th and 7th inst. Work on the dock has been greatly delayed by the boilermakers' lock-out which continued from April 30 to November 26, 1923.

The dock is of the sectional box type, in seven sections, and is capable of lifting and accommodating a vessel of 60,000 tons displacement. Its principal dimensions are: length, 960 ft., including a platform 51 ft. 9 in. in length at each end; the overall width is 170 ft. and the clear width 130 ft. 8 in., the walls are 50 ft. high and the depth of the pontoon 20 ft. 6 in., making a total height of structure of over 70 ft. The keel blocks are 4 ft. 6 in. high, and when the dock is sunk sufficiently to give a draught of 38 ft. above the top of the keel blocks, the freeboard of the side walls is 6 ft. 6 in. The total weight of the dock, including machinery, timber, fittings and equipment is about 18,800 tons. The sectional form of the dock permits of self-docking; the length can be increased at any future time by the addition of a new section.

The 14 main pump motors are being manufactured by Messrs. Cromptons, Chelmsford, allied to Messrs. Armstrong, Whitworth and Co. There is one motor on each side for each section. The 10 motors for the five central sections are each of 130 b.h.p. and the four motors for the two end sections each of 95 b.h.p., making a total of 1,680 b.h.p., or 1,250 kw. Each motor drives a centrifugal pump in the bottom of the dock by means of vertical shafting. The pumps are manufactured by Messrs. Worthington-Simpson, Limited. Three motor-driven air ejectors are fitted on each wall to counteract the tendency of the pumps to draw air, which occurs more particularly towards the end of the operation of lifting a vessel. Water is admitted to the dock by special inlet pipes provided with screw-down valves worked by hand from the top deck, the pipes branching from the main drain. The inlet pipes are also provided with flap valves, which, together with the direct lift compartment valves, are operated by means of the Westinghouse electro-pneumatic valve control system from the valve houses. A complete series of tables, depth indicators and telephones are provided, also fire and washdown pumps.

Special consideration has been given to the blocks and supports in view of the great weight of the ships to be lifted. There is a continuous timber base from end to end of the dock, on the centre line, on top of which are fitted cast steel wedge blocks with a timber block on top. The bilges of vessels are supported by two types of bilge blocks, single web and double web, consisting of steel bases with timber blocks, adjustable to suit the bilges by an addition of soft wood capping pieces. Four electrically-driven side shores are on each side of the dock; each shore is 63 ft. long, opposite pairs being geared together and driven by one motor, so that the ship is automatically centred. The side shores have two speeds, fast and slow, when extending towards the centre of dock. The mechanical side shores have been manufactured by Messrs. Clarke, Chapman and Co, Gateshead. A centreing device indicates that the vessel is in the central position before lifting is commenced. A 3-ton electric warping capstan is at each end of the top deck of each wall to deal with hauling chains, &c., about the dock. The two capstans at the bow end are used for opening and closing a pair of flying gangways giving access from one wall to the other.

All parts of the interior and exterior of the dock are accessible by ladders; the usual fittings, bollards, fair leads, ring bolts, are provided. There are two rows of air mains along each wall, and at suitable intervals air cocks are fitted to which air hose can be attached for working pneumatic tools. The dock will be electrically lighted in such a manner that the light can be concentrated in any position of the dock and of the vessel. Sanitary accommodation, shelters, fresh water tanks are provided. Four mooring booms, 110 ft. long each, are to connect the dock to a reinforced concrete dolphin on the shore. The central compartments of the dock are coated with "Humidine," the remaining parts being coated with bitumastic solution of Messrs. Wailes Dove and Company's manufacture.

It is anticipated that the dock will be connected together ready for towing to the site at Southampton at the commencement of April and completed, ready for use, at the end of the same month.

COLD STORAGE INSTALLATION AT BLACKFRIARS, LONDON.

To the Editor of Engineering.

Sir,—Our attention has been drawn to a statement contained in an article appearing in your issue of January 11 last, describing the cold-storage plant we installed at Blackfriars, London. The statement says: "The type of machine which has rendered this increase of capacity possible has been designed by Messrs. L. Sterne and Co., Limited, as the outcome of a very long experience with refrigerating machinery, &c., &c."

This statement is misleading, and we feel, in justice to Messrs. H. J. West and Co., Limited, of 72-74, Grays Inn Road, London, and Saxilby Ironworks, Lincoln, that it should be stated that the type of machine illustrated and described in your article was designed and patented by Messrs. L. Chew and W. F. Jennings, directors of H. J. West and Co., Limited, and that our company, Messrs. L. Sterne and Co., Limited, build these machines in their works at Glasgow, under licence from Messrs. H. J. West and Co., who also manufacture and sell the same type of machine.

We should be obliged if you would give early publicity to the correction, and oblige.

Yours faithfully,
for L. Sterne and Co., Limited,
S. R. Beale, Managing Director.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—The absorption of unemployed continues in the heavy trades, though conditions must improve considerably before they can be regarded as satisfactory. The steel furnaces are accounting for an output which is estimated to be well in excess of the pre-war level. The recent expansion of business in railway materials has been responsible for a much healthier demand for acid steel. Manufacturers of crude steel are up against the problem of revived competition from Belgium and France, imported supplies of semi-finished materials being available up to 2*l.* per ton below local quotations. The steel foundries report rather more active conditions, but work at rolling mills is spasmodic, production being subject to frequent stoppages. In the main, quotations are firm with little variation below those obtaining at the close of last year, though in view of the weight of overhead charges which manufacturers are called upon to bear, prices, in many instances, barely cover working costs. Official quotations are as follows: Hard basic steel billets, 10*l.* per ton; soft basic steel billets, 9*l.*; West Coast hematites, 6*l.*; East Coast hematites, 5*l.* 5*s.*; Lincolnshire No. 3 foundry iron, 4*l.* 16*s.*; Lincolnshire forge, 4*l.* 14*s.*; Derbyshire No. 3 foundry, 4*l.* 15*s.*; Derbyshire forge, 4*l.* 12*s.* 6*d.*; bars, 12*l.* 10*s.*; sheets, 15*l.*; in each case delivered at local works. The result of the more active demand recently experienced in general engineering is seen in the steady revival in the tool and implement trades. Production of saws and files is notably on the upgrade, and there is a much better call for small tools and appliances. The requirements of agricultural engineers are still depressed owing to the restriction of overseas purchases, but on home and colonial account rising sales are reported in farm and garden tools. Electrical and automobile fittings are a feature of current enquiries. Rustless iron is going into increased consumption in the building trades.

South Yorkshire Coal Trade.—More normal conditions have now been restored at collieries, though the supply of empty wagons still leaves much to be desired. Contract bookings are absorbing virtually the whole output of best steams, shipments to the Continent being a prominent feature. Home requirements, too, are again in the ascendant. Cobbles and nuts are in steady request at unchanged rates, and there is a good demand for best quality slacks, though supplies of the last-named are more easily obtainable. Arrears of orders in house coal are gradually being overtaken, new business being slightly less active than during the past few weeks. Cokes generally comprise a strong market with little surplus production. Quotations: Best handpicked branch, 35*s.* to 36*s.*; Barnsley best silkstone, 30*s.* 6*d.* to 32*s.*; Derbyshire best brights, 30*s.* to 32*s.*; Derbyshire best house coal, 26*s.* to 27*s.*; Derbyshire best large nuts, 24*s.* 6*d.* to 25*s.* 6*d.*; Derbyshire best small nuts, 18*s.* 6*d.* to 20*s.* 6*d.*; Yorkshire hards, 25*s.* to 27*s.*; Derbyshire hards, 24*s.* to 25*s.*; rough slacks, 12*s.* 6*d.* to 13*s.* 6*d.*; nutty slacks, 10*s.* to 13*s.*; smalls, 7*s.* to 9*s.*

Canadian Iron and Steel Production.—According to *Iron and Steel of Canada*, the pig-iron production in Canada for the eleven months ending November was 820,396 tons, an increase of 114 per cent. over that of 1922, and of 48 per cent. over that of 1921. The steel ingots and castings produced during the same period showed a total of 843,522 tons, 48 per cent. greater than for the corresponding period of 1922 and 26 per cent. greater than for the same months of 1921.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

Cleveland Iron Trade.—Continental competition is still keen in markets abroad, and whilst it is less severe for orders in this country, comparatively cheap parcels of foreign iron are still purchasable for consumption here. Production of Cleveland pig iron continues in excess of requirements, with the result that stocks are steadily accumulating and are now rather heavy at some makers' yards. One of the principal firms here has changed a Cleveland pig-iron furnace on to ferro-manganese, and has another Cleveland pig-iron furnace out of operation. Values tend downward, though makers are very reluctant to acknowledge actual fall. No. 1 is 100*s.*; No. 3 g.m.b. 97*s.* 6*d.*; No. 4 foundry, 95*s.* 6*d.*; and No. 4 forge, 94*s.* 6*d.*—all f.o.t. makers' works and f.o.b. Tees.

Hematite.—There is a rather easier feeling in East Coast hematite. Producers in this branch have still a good deal of work on hand, but sales are slow, and there are firms ready enough to make price concessions to secure contracts to follow on orders running out. The general market quotations for Nos. 1, 2 and 3 is 101*s.* 6*d.*, and No. 1 is put at a shilling above that figure.

Foreign Ore.—Transactions in foreign ore are very few. Sellers still base market rates on best rubio at 24*s.*, c.i.f. Tees, and more than hint that they will have to ask more if the high freights are maintained.

Blast-furnace Coke.—The downward movement in bast-furnace coke continues, but even yet prices are a good deal too high to meet the views of users. Durham, good average qualities, are offered freely at 34*s.* to 34*s.* 6*d.*, delivered to consumers in this district.

Manufactured Iron and Steel.—Very little new of moment is ascertainable concerning the various finished iron and steel departments. More liberal distribution of specifications for shipbuilding material is assisting steel-works to keep busily going, but new orders are not numerous. At the same time, some improvement in inquiry reported is gratifying. Common iron bars are 12*l.*: iron rivets, 14*l.*; packing (parallel), 9*l.*; packing (tapered), 12*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge and tank plates, 10*l.* 5*s.*; steel angles and joists, 10*l.*; heavy sections of steel rails, 9*l.*; fish plates, 13*l.*; black sheets, 13*l.* 5*s.*; and galvanised corrugated sheets, 18*l.* 10*s.*

Plant and Tools for Jerusalem.—We are officially informed that the Director of Public Works, Russian Buildings, Jerusalem, desires to receive regularly from manufacturers catalogues, price lists and other advertising literature concerning all kinds of plant, tools, instruments and materials requisite for general public work, including road building, water and electricity supply, building construction, drainage, &c.

The Late Mr. Andrew Douie.—We regret to have to record the death, which occurred on the 8th inst. at his residence, North Lodge, Walker-on-Tyne, of Mr. Andrew Douie, manager of the Walker shipyard of Messrs. Sir W. G. Armstrong, Whitworth and Co., Limited. Mr. Douie was born at Moira, County Down, Ireland, and served his apprenticeship with Messrs. Harland and Wolff, Belfast. He entered Messrs. Armstrong's Walker shipyard in 1887, and was sent by them to Russia in 1895 to superintend work on the Volga; in 1899 he was sent to Siberia to build up the ice-breaking train ferry Baikal and the ice-breaker Angara, both of which had been constructed by Messrs. Armstrong and delivered in sections to the shores of Lake Baikal. On completion of this work, Mr. Douie proceeded to South Africa on behalf of Messrs. Swan, Hunter and Wigham Richardson, Limited, to supervise the testing and taking delivery of the floating dock for Durban, built by them. On his return, in 1904, Mr. Douie was appointed yard manager at Messrs. Armstrong's Walker shipyard, and in 1920 he succeeded Mr. D. R. MacDonald as manager. He was held in great esteem by his employers and all his subordinates.

Losses of Merchant Shipping.—According to statistics just issued by Lloyd's Register of Shipping, the world's losses of merchant shipping during the quarter ended September 30 last amounted to 119,627 gross tons, comprised in 86 vessels. Great Britain and Ireland lost 20 ships, making 24,232 tons, during the period, but the latter figure is only 0·13 per cent. of the total tonnage owned in this country. In the case of the United States, the losses amounted to 20,995 tons (eight ships), but the proportion of the total American tonnage lost is slightly greater than that for Great Britain and Ireland, viz., 0·14 per cent. Japan lost 0·34 per cent. of her merchant tonnage during the quarter under review, the losses including seven vessels with an aggregate tonnage of 12,089. For Norway the losses amounted to 11,260 tons, or 0·44 per cent. of the total tonnages, and the corresponding figures for Germany and France, respectively, were 10,543 tons (0·41 per cent.) and 6,636 tons (0·18 per cent.). In proportion, the heaviest losses during the quarter were suffered by Greece, the three ships making, 9,069 tons, lost by that country amounting to 1·2 per cent. of the total Greek tonnage. The above-mentioned figures include steamers, motor ships and sailing vessels of 100 gross tons and upwards, but the totals exclude cases of breaking up, condemnation, &c., which are not known to be consequent upon stress of weather, &c. If such cases are included, the total losses for the whole world amount to 354,419 tons comprised in 1914 vessels.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The conditions in the Scottish steel trade have varied very little over the week, and managements are still on the lookout for new business. This is very difficult to pick up, and if the threatened trouble among the dockers and the shipyard workers comes to anything, dealings will get another set-back. At the time of writing, it looks more hopeful that a satisfactory agreement will be reached with the dockers and that a stoppage will be averted, but with regard to the shipyard workers the demand for an increase in wages is only in the initial stages. Steelmakers generally are very quiet, and orders on hand are only managing to keep the works moving in a kind of way. Inquiries, while good, are not resulting in much fresh business either on home or foreign account. In the black sheet trade there is quite a fair amount of work going on not only in the light but also in the heavier gauges. Order-books are well filled, and a steady run is more than probable for some time to come. The export trade over all is not brisk, and what there is will decrease if there is any prolonged stoppage of work at the docks. There has been no alteration in home prices this week, and the following are the current quotations: Boiler plates, 13*l.* 10*s.* per ton: ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—Business in the malleable iron trade of the West of Scotland continues very much on hand-to-mouth lines, but it is quite astonishing at times how steadily some of the works are kept running. The re-rolled steel branches have been doing fairly well, but the demand is again easier. Prices are steady, with "Crown" bars called 12*l.* 10*s.* per ton, delivered Glasgow stations.

Scottish Pig-Iron Trade.—In the Scottish pig-iron trade the demand has not been very heavy of late, and the current output has been equal, in most cases, to all requirements. Generally speaking, it is old contracts which are keeping the furnaces in operation, as new business is very scarce, despite a fair inquiry. Prices show little change, and are as follows: Hematite, 5*l.* 8*s.* 9*d.* per ton, delivered at the steel works; foundry iron, No. 1, 5*l.* 10*s.* per ton, and No. 3, 5*l.* 2*s.* 6*d.* per ton, both on trucks at makers' yards.

Scottish Pig-Iron Shipments.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, February 9, amounted to 1,088 tons. Of that total 896 tons went foreign, and the balance of 192 tons went coastwise. For the corresponding week of last year the figures were 4,116 tons abroad and 781 tons coastwise, making a total shipment of 4,897 tons.

AWARD OF THE BESSEMER MEDAL OF THE IRON AND STEEL INSTITUTE.—The Council of the Iron and Steel Institute has decided to award the Bessemer Gold Medal this year to Professor Albert Sauveur, of Harvard University, in recognition of his eminent services in the advancement of the science of the metallurgy of iron and steel. Professor Sauveur hopes to make the journey to London in order to receive the Medal at the hands of Sir William H. Ellis, G.B.E., who succeeds to the Presidency at the Annual Meeting of the Institute on May 8 and 9.

ITALIAN ENGINEERS AND THE UNITED STATES.—We read in the *Iron Trade Review*, Cleveland, Ohio, that the American Engineering Council will aid the Italian Ambassador in furthering "intellectual immigration" from Italy. Fifty young Italian engineers, recent graduates of technical schools, will sail soon for New York, thence to be sent to industrial centres to become simple labourers in large manufacturing plants. The vanguard of 50 will soon be followed by 100 more, annual migrations being planned. The American Engineering Council, in response to a communication from the Ambassador, has decided to co-operate with the Italian Embassy and the United States authorities in securing places for the Italians and in looking after their general welfare and seeing them well employed.

A LONG, HIGH-PRESSURE STEAM PIPE LINE.—What is thought to be the longest high-pressure steam pipe line in the world has recently been completed and is now in service for the Pittsfield (Mass.) Electric Company. It is 3,610 ft. in length and carries steam at a pressure of 195 lb. per sq. in. from the company's Silver Lake power plant to a station in the city of Pittsfield, where the steam is used to operate a 750 kw. turbo-generator. The pipe is 8 in. in diameter, of cast steel, and has been made in 40 ft. lengths. For one-third of its length it is laid in a concrete conduit underground, but the remainder is supported above ground level on rollers mounted on concrete blocks. The rollers are employed to facilitate the movement of the pipe between the expansion joints, which are inserted at points 210 ft. apart with semi-rigid anchorages in between; the total expansion and contraction to be provided for amounts to about 7 ft. Loss of heat is reduced, as far as possible, by a 3 in. covering of insulating material, which includes two ½ in. layers of fireproof felt and a layer containing 85 per cent. of magnesia. This is protected by a heavy duck covering, and the whole is rendered weatherproof by a three-ply wrapping of Ruberoid roofing paper. An automatic isolating valve has been provided at the inlet end of the line to cut off the steam in case of accident, and our American contemporary, *Power*, from which we quote the above particulars of the installation, states that the exhaust steam from the turbo-generator will be utilised for heating a block of business premises in Pittsfield.

NOTICES OF MEETINGS.

THE INSTITUTE OF METALS—Sheffield Local Section.—Friday, February 15, at 7.45 p.m., at Albany Hotel, Fargate. Joint meeting with the Institution of British Foundrymen.

THE INSTITUTE OF METALS.—Swansea Local Section.—Friday, February 15, at 7.15 p.m., in the Metallurgical Department, University College, Singleton Park. Paper on "Fatigue and the Elastic Limit," by Professor Cecil H. Desch, D.Sc., Ph.D., F.R.S.

THE INSTITUTION OF CHEMICAL ENGINEERS.—Monday, February 18, at 8 p.m., at the Engineers' Club, 39, Coventry-street, W.1, when Mr. D. M. Newitt (Associate Member) will read his paper on "The Transport, Storage and Distribution of Hydrochloric Acid."

THE FARADAY SOCIETY.—Monday, February 18, in the rooms of the Chemical Society, at 8 p.m., Principal A. P. Laurie will put forward some suggestions for a magnetic theory of valency.

THE INSTITUTION OF CIVIL ENGINEERS—Newcastle-upon-Tyne Association.—Monday, February 18, at 7.30 p.m. Lecture Theatre, Neville Hall, Newcastle-upon-Tyne. Paper by Mr. W. Simpson, O.B.E., M.Inst.C.E., on "Some Applications of Reinforced Concrete in Harbour and Dock Construction."

BRADFORD ENGINEERING SOCIETY.—Monday, February 18, at 7.30 p.m., in the Hall of the Bradford Technical College, Mr. A. Spittle (Smethwick) on "The Manufacture of Seamless Drawn Tubes and Sheets of Brass and Copper." Illustrated by lantern slides and the cinematograph.

THE ILLUMINATING ENGINEERING SOCIETY.—Tuesday, February 19, at the Royal Society of Arts (John-street, Adelphi, London), at 8 p.m., when a discussion on "Some Aspects of Railway Lighting" will be opened by Mr. J. F. Caine and Mr. E. A. Marx.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, February 19, at 7.30 p.m., in the Rankine Hall, 39, Elmbank-crescent, Glasgow. Paper, "Manœuvring of Ships. Part II. Unbalanced Rudders of Twin-screw Ships," by Mr. G. H. Bottomley.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, February 19, at 6 p.m., at Great George-street, S.W.1. Ordinary meeting. Papers to be submitted for further discussion: "Slips and Washouts on the Hill Section of the Assam-Bengal Railway," by Thomas Richard Nolan, B.A., B.E., M.Inst.C.E.; "Underdrainage and its Application to Railway Work," by Reginald David Walker, M.C., Assoc.M.Inst.C.E. Wednesday, February 20, at 6 p.m. Students' meeting. Paper, "The Reconstruction of an Important Bridge on the London Midland and Scottish Railway," by Charles Brandon Trye.

ROYAL SOCIETY OF ARTS.—Wednesday, February 20, at 8 p.m. "New Uses for Rubber," by Percival James Burgess, M.A., F.C.S., chairman of the Rubber Growers' Association. Sir Stanley Bois, president, Ceylon Association in London, will preside.

LIVERPOOL ENGINEERING SOCIETY.—Wednesday, February 20, at 8 p.m., at the society's rooms, when the following paper will be read: "Steel Castings," by J. Varley, M.Sc., Assoc.M.Inst.C.E.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, February 20, at 7.30 p.m., at 49, Cromwell-road, South Kensington. The following papers will be read: (1) "The Lunar Atmospheric Tide at Mauritius and Tiflis," by Professor S. Chapman, F.R.S. (2) "The Semi-diurnal Oscillation of the Atmosphere," by Professor S. Chapman, F.R.S. (3) "The Relationship between Current and Wind," by C. S. Durst, B.A.

THE INSTITUTION OF MINING AND METALLURGY.—Thursday, February 21, at 5.30 p.m., at the Rooms of the Geological Society, Burlington House, Piccadilly, W.1. The following papers will be submitted for discussion: "Dielectric Separation: a New Method for the Treatment of Ores," by H. S. Hatfield, B.Sc., Ph.D.; "Dielectric Mineral Separation: Notes on Laboratory Work," by B. W. Holman and St. J. R. C. Shepherd; "The Influence of Certain Fluxes on the Softening Temperature and Fluidity of a Monosilicate Mixture of Lime and Soda," by W. S. Patterson, M.Sc., and P. F. Summers.

THE INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, February 21, at 7.30 p.m., at Denison House, 296, Vauxhall Bridge-road, S.W.1, a paper will be read entitled "Column Fallacies," by E. H. Salmon, D.Sc., A.M.Inst.C.E. The paper will be illustrated with lantern slides.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, February 22, at 6 p.m., at the Institution, annual general meeting. The annual report of the Council will be presented. Probable resumption of discussion on "Repairs and Upkeep of Pneumatic Tools," by R. W. Wilson, of Newcastle-on-Tyne.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, February 22, at 39, Victoria-street, at 7.30 p.m., lecturette, "Ciment Fondu: Its Manufacture and Special Uses," by J. S. Marshall. Saturday, February 23, at 2 p.m. Visit to the British Empire Exhibition Construction at Wembley, to inspect the railway of Never-Stop Transit, Limited, in course of erection.

ROYAL INSTITUTION OF GREAT BRITAIN.—Afternoon lecture, Thursday, February 23, at 5.15 p.m., Sir William Bragg, D.Sc., F.R.S., on "Crystalline Structure of Organic Substances" (Lecture III).

HULL ASSOCIATION OF ENGINEERS.—Saturday, February 23, at 7.15 p.m., at the Municipal Technical College, Park-street, Hull, lecture on "Incandescent Lamps, Wireless Valves, &c.," by Dr. C. E. Hiatt.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Some interesting facts are revealed in the Board of Trade returns of the finances of the coal trade in the quarter ending September last. With regard to South Wales, it is shown that the quantity raised was 12,100,000 tons, or nearly 1,000,000 tons less than in the June quarter, and that the amount commercially disposable was 11,100,000 tons, a reduction of about 800,000 tons. The proceeds amounted to 12,400,000*l.*, or nearly 500,000*l.* less than in the June quarter, and the net cost of production to 11,700,000*l.*, an increase of nearly 1,000,000*l.*, while the credit balance at 670,000*l.* showed a reduction of 1,482,000*l.*, the profit declining from 3*s.* 10*d.* to 1*s.* 2*d.* per ton. The cost of production was increased from 19*s.* 4*d.* to 21*s.* 3*d.* per ton, of which the wages cost amounted to 14*s.* 4*d.*, compared with 12*s.* 9*d.*, that of stores and timber to 3*s.*, against 2*s.* 10*d.*, and other costs to 3*s.* 1*d.*, against 2*s.* 11*d.* The advance in the wages cost was due to the fact that in July and August the general wage rate is 17·62 per cent. in excess of the minimum. At present the coal market is in a strong position. Collieries generally are well booked, and shippers, in view of the threatening labour outlook, are displaying anxiety to get supplies away. This is particularly the case so far as depot proprietors are concerned, notwithstanding an appreciable advance in freights. On the other hand, the collieries are so well booked up and have such an abundance of shipping in dock, that they have scarcely any free coal available. In fact, there has been a daily list of from 70 to 80 vessels waiting for berths. The congestion is to a large extent due to the absence of third shift working at the docks, which restricts the railway in getting wagons back to the collieries. The Egyptian State Railways have contracted for 200,000 tons of Monmouthshire coal, and one of the Spanish railways is in the market for 22,000 tons of second Admiralty large, while heavy supplies are going to the foreign coaling depots. For best Admiralty large coal 30*s.* to 31*s.* are demanded and seconds command 30*s.*, while Monmouthshires range from 27*s.* 6*d.* to 29*s.* 6*d.*, with drys from 27*s.* to 28*s.* 6*d.* Best steam smalls rule from 22*s.* to 23*s.* and other grades from 17*s.* to 22*s.* 6*d.*

Rise in Freights.—During the past week there has been a considerable improvement in outward coal freights, especially for the Mediterranean and South American ports. In the near trades there has also been a small improvement. The general inquiry has been active, and tonnage has not been in sufficient supply to meet charterers' requirements. The rate for West Italy for instance, has jumped from 8*s.* 9*d.* to 11*s.* 6*d.*, and owners are talking about 12*s.*, for Alexandria from 9*s.* 6*d.* to 11*s.* 6*d.*, for Barcelona from 11*s.* 6*d.* to 13*s.*, for Gibraltar from 8*s.* to 9*s.*, for Port Said from 9*s.* 6*d.* to 11*s.* 4½*d.*, and for the River Plate from 12*s.* to 15*s.*

Iron and Steel.—Exports of iron and steel goods from South Wales last week amounted to 11,609 tons, compared with 19,956 tons in the previous week. Shipments of tin plates and terne plates amounted to 7,418 tons, compared with 11,699 tons; black plates and sheets to 3,727 tons, against 5,367 tons; galvanised sheets to 341 tons, against 1,620 tons; and other iron and steel goods to 123 tons, against 1,270 tons.

NORWAY SUBMARINE BOATS.—Submarine No. B 3 was recently launched at Kaldnes Dockyard, Tosberg. She displaces 420 tons on the surface and 590 tons submerged; her indicated horse-power is 900, surface speed 14½ knots, and her speed below water 10 knots. She is 167 ft. long, and is armed with two bow and two stern tubes.

SWEDISH IRON AND STEEL IN 1923.—At the meeting of the Union of Swedish Ironmasters it was stated that, owing to labour conflicts extending over six months of the year, work was practically at a standstill for that period, but during the last five months of 1923 employment was comparatively satisfactory at most of the works, thanks to previously accumulated orders. As was to be expected, the production of wrought iron was smaller than during 1922, whereas the production of pig-iron showed an increase.

CHARTERED ELECTRICAL ENGINEERS.—A special general meeting of the corporate members of the Institution of Electrical Engineers will be held at the Institution headquarters at 5.30 p.m. on the 28th inst., to consider and, if thought fit, to pass a new bye-law by the terms of which every member and associate member of the Institution is, and is entitled to describe himself as, a chartered electrical engineer. It is proposed that the description shall be used after the designation letters M.I.E.E. or A.M.I.E.E.

VANADIUM ORES.—Owing to the importance of vanadium as an alloy to iron and other metals a booklet on vanadium ore deposits throughout the world, recently issued by the Imperial Institute, will be found of interest to metallurgists. It will also appeal to all firms interested in the dye industries. It is divided into two sections, covering the British Empire and the foreign supplies of vanadium ores, preceded by a chapter on the occurrence, characters and uses of vanadium. A map of the world indicates the vanadium-bearing districts. The book is published at the price of 5*s.* net by John Murray, Albemarle-street, W.

CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

(*For Description, see Page* 195.)

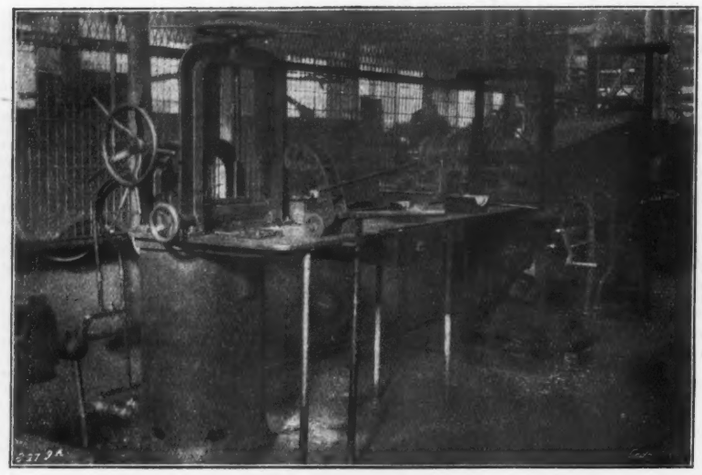


Fig. 32. Die-Casting and Shell-Heating Plant.

Fig. 33 Delivery End of Continuous Shell-Heating Furnace.

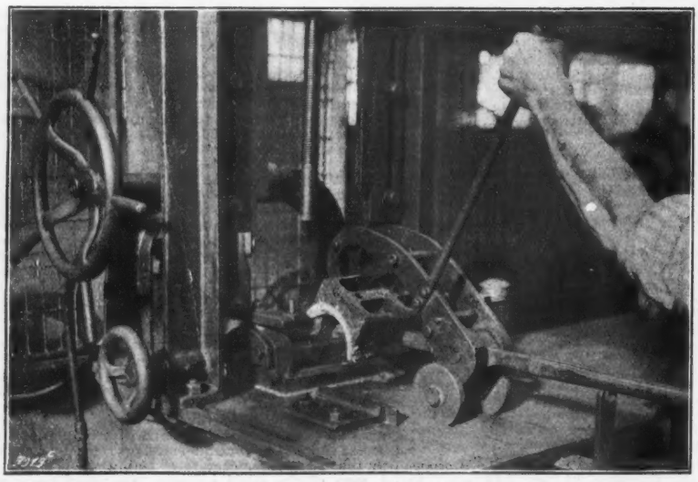


Fig. 35. Shell Grip used for Die-Casting Machine.

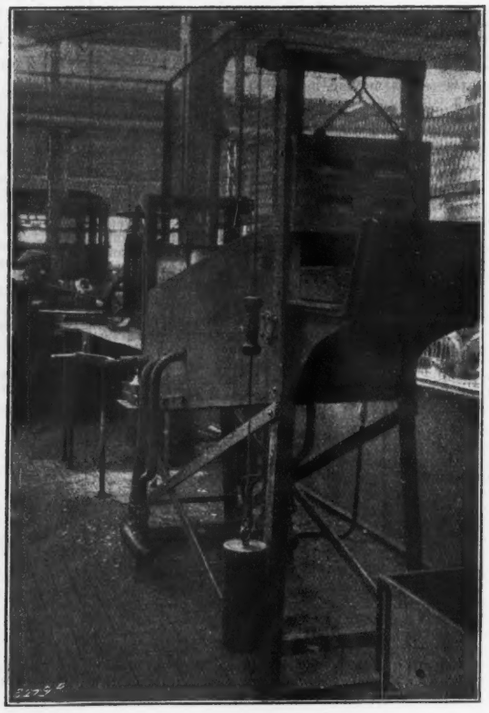


Fig. 34. Feeding End of Continuous Shell-Heating Furnace.

Fig. 36. Gas-Fired White-Metal Pot.

ENGINEERING.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received 10 days previous to the day of publication.

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Four One-Page Plates.—CAR REPAIR SHOPS OF THE LONDON UNDERGROUND RAILWAYS AT ACTON.

ENGINEERING.

FRIDAY, FEBRUARY 15, 1924.

SECONDARY STRESSES.

THE term secondary stresses is commonly very loosely defined. Some engineers would apparently classify as secondary, the stresses which arose in the bracing of the chord member of the first Quebec Bridge, when it began to show indications of failure, and apparently this view is that taken in the new Indian Bridge rules issued last year. According to these, "primary stresses" are those which would be produced if certain broad assumptions introduced to facilitate calculation were true, whilst "a secondary stress is merely a correction to allow for the approximate nature" of the foregoing assumptions. Such a comprehensive use of the term is, we believe, wholly illegitimate, but cannot well be relinquished by those who maintain that secondary stresses are of great practical importance, as by so doing they would practically abandon their case. For our own part we classify as "secondary" only such stresses as arise from the "redundancy" of members or fastenings. The bracing of a strut cannot be regarded as redundant, even although it has not been customary to calculate the stresses which may in certain conditions arise in it. If secondary stresses be defined in this way, as those due to redundancy, we have yet to learn of a single bridge catastrophe due to the existence of uncalculated secondary stresses. No doubt when these secondary stresses are alternating, cracks may develop, and indeed an instance of this occurring on shipboard was brought forward some years since at a meeting of the Institution of Naval Architects; but here again, since the stresses really were "secondary" in the sense above defined, no particular harm was done. On the other hand the failure of the bracing of a strut involves an immediate collapse, since as already noted, this bracing is in no sense redundant. Alternating stresses in bridge work are very rare. Such as do occur are commonly occasioned by change of temperature, and temperature stresses are notoriously much less serious in practice than would be anticipated from *a priori* considerations. Realising this, French engineers have not hesitated to construct arched bridges with very small versed sines, and these seem to have given full satisfaction in service. When the stresses do not change their sign, no evidence has yet been brought forward to show that secondary stresses even give rise to cracks. Indeed the very fact that the stresses are due to "redundancy" implies that any local overload is transmitted to less heavily strained parts, long before the metal will be stretched to the cracking point; and so far as we can discover the whole case put forward by those who insist on the importance of secondary stresses rests entirely on computation.

Perhaps, however, we should make one exception. In a recent editorial entitled a "Proved danger," the *Engineering News Record* brought forward two cases of failure, which it asserted to be due to uncalculated secondary stresses. Of the one case it is sufficient to say that the writer admits that he lacked particulars, whilst as to the other a correspondent who appears to be well acquainted with the failure, stated that the conditions were complicated and so little understood, that it was impossible to assign the cause. Apparently in both cases the steel work which failed was embedded in concrete which was intended to take in part the place of more legitimate forms of bracing, so that the natural conclusion to be drawn from the two incidents was that the failure occurred through lack of stiffness rather than from an excess of it.

Everyone knows, of course, the elementary proposition in applied mechanics, by which it has been shown that adding a thin fin to a rectangular bar, so as to make it in a T with a very thick table and slender stalk, leads to the result that the bending stress due to a stated transverse load has been increased by the additional metal. Everyone also knows, however, that in practice under a non-alternating stress the T-beam thus produced is stronger, not weaker, than its table taken alone. Hence the high calculated stress in the thin stalk is entirely fallacious as evidence of the real factor of safety.

Nevertheless, though every practical man knows this it is very difficult for the modern engineer to act on this knowledge. On this head his predecessors knew as much as himself, but being ignorant of modern refinements in stress analysis, their practical experience was undisturbed by computations which indicate that calculated secondary stresses are in some cases higher than the designed primary stresses. It must be admitted that the position is not without difficulty. There is something positive about a calculation, whilst in this matter experience has a certain negative characteristic. The maintenance engineer can merely say that his bridges, calculated on the old assumption are not subject to cracked plates or loose rivets, but he can no more put into figures the real factor of safety than could Silas Wegg, the value of the business from which Mr. Boffin had taken him. The mere computer is, of course, really in no better case, but generally fails to realise the fact.

Doctors are commonly said to make bad patients, since they know too much for their peace of mind, and we are not sure that the increase in the knowledge of stress analysis may not turn bridge designers into bad engineers. This tendency will certainly be promoted by the requirements of the new Indian Bridge rules, which demand that in the future secondary stresses must be calculated for all new bridges. This rule will tend undoubtedly to promote the adoption of designs in which real safety and security is ranked second to ease of computation. It would have been far more to the point if the authorities had laid it down, that the secondary stresses must be calculated for all existing bridges, and the results thus obtained compared with the service records.

The new rules are the outcome of a committee appointed in 1917, and constituted by representatives of the Government and of the Indian railways. This committee issued five reports, of which the most striking feature was the almost complete absence of any reference to the actual behaviour in service of the hundreds of bridges in use on Indian railways. It is pretty certain that the modern steel steamship would never have been brought to its present pitch of perfection had Lloyds and other registration societies followed a similar line. Their policy has however, been to check and control calculation by the results of experience, and it is probably to this circumstance that the elastic limit as considered by these agencies of little importance

in fixing working stresses whilst the new Indian rules contain a note to the effect that permissible stresses are supposed to bear some relation to the "elastic limit" rather than to the breaking load. The committee responsible for the rules, recommended, we note, that the number of highly qualified bridge engineers in India should be increased, but we fear that there is some reason for believing that what is here intended by the term is "highly skilled computer," who only too often is not really an engineer at all.

Indian bridge inspectors are in future to be called on to "show clearly what 'primary' and 'secondary' stresses have been calculated, and what reasons have led the inspector to assume that uncalculated 'secondary' stresses are covered by a margin between the total of the calculated secondary and primary stresses and the elastic limit." This requirement will involve a very large amount of tedious, though no doubt intrinsically simple calculation, and there is every reason for believing that its results will be the reverse of satisfactory.

There is, perhaps, one argument in favour of the new departure. The engineer is responsible for the safety of passengers travelling over his bridges, and should an accident occur, no matter from what cause, and an inquiry result, it would be distinctly inconvenient if some ambitious barrister were to learn that certain secondary stresses were higher than the nominal official limits. One can readily imagine how the smart lawyer would present the fact to a coroner's jury. An illustration of what might be expected was afforded by the Titanic inquiry, in which although there was no doubt as to the real cause of the disaster, a counsel briefed by the Labour unions undertook to prove that the ship was structurally weak. The only point he really did succeed in establishing was, however, his own lack of acquaintanceship with elementary questions in physics and mechanics; and as the court had the assistance of technical assessors no harm was done. A coroner's jury, however, would lack such guidance, and it might be difficult to justify to them the existence of nominally high but really unimportant stresses. As a matter of fact, it may be noted that the late Sir Benjamin Baker estimated the stresses on the Conway and Britannia tubular bridges at some 6 tons per square inch, the material used being the ordinary iron commercially available at the time of erection; and the Board of Trade limit for such iron being 5 tons per square inch at the date of Sir Benjamin's address.

Possibly this fear of the lawyer has not been without its inference on American Bridge designers, who are also nowadays attaching very great importance to secondary stresses. Here again, the contention is supported solely by computation and not by a recital of observed facts.

It has become increasingly the practice in the States to replace pin joints by riveted connections, owing to the very satisfactory record of these in service. With pin joints, however, the designer might not unreasonably assume the absence of large secondary stresses in the members connected. No doubt such joints are not wholly free, but vibration is a wonderful eliminator of friction, and it seems quite probable that in service pin jointed members take up positions in which the secondary stresses due to frictional fixation are insignificant. It is impossible to hold a corresponding view when the joints are rivetted, and consequently secondary stresses may be very high. It is this which seems to have alarmed many American bridge engineers and text-book writers, some of whom insist that all web members shall be made shallow in the direction in which the fixation of the joint would give rise to bending stresses. This view, so far as can be learnt, is not based on any history of failure where the precaution cited has been neglected, but rests wholly on computations. The recommendation seems, however, contrary to good practice. It makes more difficult the satisfactory design of the joints, and it is not easy to see that any compensating advantage is gained. Certainly so far as the tension members are concerned it is useless, and in the case of the compression members it seems positively detrimental. As usually constructed such members are weakest transversely, and not in the plane in which secondary bending may occur. Thus the Quebec chord failed by lateral yielding, and not in the vertical plane. The plan seems, however, to be in favour, and has had one remarkable development. Thus, in some recent American bridges the web members are being erected with an initial curvature in their neutral axes. This curvature is the reverse of that which calculation indicates will be produced by the secondary bending stresses, so that under their designed load the neutral axes of the members will become straight.

As we understand the matter the designers responsible for this departure have first of all reduced the stiffness of the member in the plane of bending, and have then sought to correct the consequent distortion by the procedure above described. It was a Western doctor who on being called in to prescribe for a case of measles admitted his ignorance of this disease, but proposed instead to give the child fits, as he claimed to be a "demon at curing fits." There seems a certain analogy between this procedure and that above described. No case is on record of struts failing because of being too stiff, but the bridge doctor in a quandary as to what to do in respect to secondary stresses, has in this case first of all weakened his strut and has then attempted to make good in the fashion above described.

BOILER TESTS WITH PREHEATED AIR.

IT is now generally recognised that substantial economy may be effected by the use of preheated air in boiler furnaces, and it is likely that considerable developments will take place along these lines in the near future. The preheating of the air for combustion by means of the flue gases not only returns to the furnace many heat units which would otherwise escape, but it has certain incidental advantages which should not be overlooked. There is no doubt that the heated air facilitates the combustion of the fuel with the result that the amount of excess air passed through the fire can be reduced and a consequent improvement in the efficiency of the plant can be obtained. Another secondary effect is the increase of the furnace temperature, and it is a fear that their brickwork may be melted or their grates burnt which has undoubtedly caused engineers to adopt a very cautious attitude towards experiments with preheated air. Experience, however, shows that the advantages of the practice may be obtained without any very serious results following, for the temperature of the furnace rises very much less than is generally supposed, owing no doubt to the predominating part played by the direct radiation of heat to the boiler surfaces.

Everything which adds to our knowledge of the practical results of using preheated air is particularly useful at the present time, and considerable interest therefore attaches to a paper read last Monday before the Institution of Engineers and Shipbuilders in Scotland by Mr. W. H. Owen, who described some tests carried out on a Scotch marine boiler, with and without an air preheater. The boiler in question was of the single-ended type 9 ft. 6 in. diameter by 11 ft. long with two furnaces. It was fitted with an air-preheater of the Howden-Ljungström design, in which the air and the flue gases are caused to pass axially through opposite sides of a slowly rotating heat regenerator. The air is thus drawn continually over freshly heated surfaces, and, as the action does not depend in any way upon the transmission of heat through metal, the heat transference is highly efficient. We illustrated and described this type of heater very fully at the time of its development by Mr. Ljungström (see ENGINEERING, vol. cxiv, page 24), so that we need not refer to it now in any detail.

For particulars of the methods of testing and of the precaution taken to ensure accuracy, we would refer our readers to Mr. Owen's paper. The principal results are summarised in Table I, which we reproduce below. It will be seen that a boiler efficiency of as high as 89·7 per cent. was recorded with oil as fuel, and 88·1 per cent. with coal firing. These figures, it should be noted, are calculated on the basis of the lower calorific value of the fuel, which in the opinion of many power station engineers ought to be abandoned, but so long as it remains the "official" method, manufacturers are, of course, justified in using it. The air temperature at the boiler front was, in one test as high as 491 deg. F., the average temperature of the six tests with preheated air being over 450 deg. F. It will also be remarked that the temperature of the exit flue gases was extraordinarily low, in one case only 200 deg. F. being recorded. In tests (1) and (6), details of which are given elsewhere in the paper, the flue-gas temperatures before entering the heater were respectively 574 deg. F. and 583 deg. F., so that in these two cases temperature reductions of 365 deg. F. and 351 deg. F. were effected by the heater.

The second test recorded in the table was made to determine what the effect upon the efficiency of the boiler would be of blinding off a certain length of the tubes from the smokebox end. Experiments carried out many years ago proved that in the case of a locomotive boiler almost the whole of the evaporation was obtained from the firebox and the portions of the tubes immediately adjacent, the smoke-box ends of the tubes contributing very little. A corresponding effect was reasonably expected in the case of a marine boiler, so to determine the heating value of the last portion of the tubes to be traversed by the gases, Mr. Owen shortened the effective tube length from 7 ft. 6 in. to 5 ft. 6 in. by inserting asbestos sleeves from the front end. These sleeves did not fit the tubes tightly but the ends of the annular spaces around the sleeves were plugged to prevent the passage of hot gases except through the sleeves. The boiler was fired at practically the same rate as in the first test. The blinding off of the ends of the tubes did not prevent an efficiency as high as 87·0 per cent. being obtained, and the gas temperature at the chimney base was actually lower than when the whole tube surface was in use. The "from and at" evaporation was raised from 6·98 lb. to 8·4 lb. of water per square foot of heating surface, and the inlet temperature to the furnaces from 435 deg. F. to 463 deg. F. A higher air temperature occurring simultaneously with a lower flue gas temperature is not unusual, and bears out our remarks above on the effect of radiant heat.

TABLE I.—PRINCIPAL RESULTS DEDUCED FROM THE TESTS.

1. Test No.	1	2	3	4	5	6	7
2. Duration in hours	4	4	2 hr. 57 min.	2	3	4	5
3. Condition of air	Preheated	Preheated	Preheated	Preheated	Preheated	Preheated	Nat. draught
4. Fuel	Oil	Oil	Oil	Oil	Oil	Coal	Coal
5. Steam pressure, lbs. per square inch, gauge	186·0	186·5	186·3	186·0	184·1	185·0	180·0
6. Quality of steam (dryness)	0·984	0·986	0·985	0·987	0·987	0·979	0·979
7. Fuel consumption, lbs. per hour	454·75	455·5	436·9	437·0	426·0	632·0	440·0
8. Nett calorific value, B.Th.U.'s	17,415	17,480	17,480	17,502	17,433	13,228	14,201
9. Water evaporated, lbs. per hour	6,703·0	6,565·0	6,359·3	6,382·5	6,123·3	6,982·0	3,914·4
10. Water evaporated, lbs. per hour per lb. of fuel	14·74	14·41	14·55	14·60	14·37	11·0	8·89
11. Water evaporated, lbs. per hour per square foot of heating surface	6·4	7·77	6·14	6·16	5·91	7·67	4·3
12. Air pressure at boiler front, inches of water	0·18	0·60	1·0	0·58	2·5	0·33	—
13. Air temperature at boiler front, °F.	435	463	491	447	450	436	—
14. Gas temperature chimney base, °F.	209	204	212	200	217	232	536
15. CO_2 in flue gases (smoke-box per cent.	13·63	14·1	11·7	12·56	8·19	13·0	10·0
16. Boiler efficiency, per cent.	89·7	87·0	88·2	88·5	87·4	88·1	66·17

The object of the third, fourth and fifth tests was to ascertain what variation in efficiency would be caused by varying the amount of air, the quantity of oil burnt being kept as constant as possible. A special fan was used to give the draught required. A study of the figures will show how comparatively slightly the efficiency varies with different percentages of CO_2, when the heat in the exit gases is largely returned to the furnace by an air preheater. The last two tests in the table, which refer to coal firing were carried out by Professor W. J. Goudie. The first of these was made when burning coal at the rate of 26·3 lb. per square foot per hour, with preheated air, the efficiency being 88·1 per cent. The last test was made under natural draught conditions with cold air. The evaporation of the boiler was notably reduced and only 18·3 lb. of coal was burned per square foot of grate area per hour. The efficiency fell from 88·1 to 66·17 per cent., although the coal in the second test was of better quality than in the first. The results of these two tests are sufficient to show in a striking manner how great a saving in fuel, and how much more duty can be obtained from a marine boiler when operated with preheated air and forced draught, than can be obtained under natural draught. The conditions are not, of course, comparable with those under which the water-tube boilers of power stations are operated, but the tests we have quoted should do much to reassure those engineers who are unduly afraid of high temperature air in land practice. After all, air at 500 deg. F. is still 1,600 deg. below the melting point of cast iron, so that its cooling effect on the grates should not be seriously impaired, and with deep and narrow bars supporting the fire there is no reason to anticipate overheating of the grates. Overheating of brickwork, and particularly of arches, appears the greater danger, but if, as seems possible, the use of preheated air enables long projecting arches to be dispensed with, arch troubles will disappear in the best possible way.

FRENCH NAVAL BUILDING PROGRAMME.

THE Bill for authorising the second instalment of the French naval programme has been examined by the naval commission of the Chamber of Deputies, and a report has been made on it by Monsieur Paul Denise. To this report has been added another, in answer to amendments brought forward by Messieurs Morinaud, Guépratte, and Aiguier. In his first report Monsieur Denise, after reviewing the present condition of the French navy, concludes "that it would be unthinkable to stop naval building." The substance of his remarks is, therefore, that the second part of the naval programme shall be taken in hand. That programme was, originally, that the following vessels should be completed by 1930: 6 light cruisers of 10,000 tons, 15 flotilla leaders of 2,400 tons, 24 destroyers of 1,450 tons, 4 cruiser-submarines of 3,000 tons, 30 submarines of 1,300 tons, 2 minelayers of 4,000 tons, 4 oilers of 10,000 tons.

The programme allows for no first-class ships. "It has been taken into consideration that 1931 will be the critical year with regard to battleship construction . . . and that it will probably mark an important stage in the evolution of the world's navies."

The commission hesitated to approve of the 10,000 ton cruisers: "Their length and draught render them vulnerable to mines and torpedo attack, and it will be difficult to protect them efficiently against aircraft." It was, however, decided that they ought to be built, in consideration of France's great colonial empire, and her need of cruisers. Experts differ as to the form of protection which should be given to these cruisers, and nothing has been decided. They will be armed with eight 7·9 in. guns, mounted in twin turrets, and they will have a speed of between 33 and 34 knots. "It is hoped that these ships will not be inferior to those of any foreign power."

A comparison is made in the programme between the proposed destroyers and those of foreign powers, thus showing that the French vessels are superior in tonnage, horse-power and speed, with the possible exception of the Japanese boats about which exact details are at present lacking.

Their foreign competitors are: (i) the British "W" type, 29 boats, including the Witch, which has just been put into commission; (ii) the American "Farragut" type, well over 100 boats, practically all of which were built in 1918 and 1919; (iii) the Japanese "Minekase" type, 15 boats in all, built in 1920 and 1921; and (iv) the Italian "Curtatone" type, one boat only, built between 1920 and 1923. Taking these types in order, the latest information shows that the British boats have a displacement of 1,300 tons, an indicated horse-power of 27,000, a speed of 31 knots and six torpedo tubes; whilst the corresponding figures for the destroyers of the other countries are as follows: (*a*) Americans: displacement, 1,215 tons; horse-power, 27,000; speed, 33 knots; armament, four 4 in. guns and two triple 21 in. torpedo tubes. (*b*) Japanese: displacement, 1,345 tons; horse-power, doubtful, but probably about 30,000; speed, 34 knots; armament, four 4 in. guns and three double 21 in. torpedo tubes; and (*c*) Italian: displacement, 940 tons; horse-power, 27,000; speed, 34 knots; armament, four 4 in. and two triple 18 in. tubes. As against these specifications, the French boats will displace 1,450 tons, have a horse-power of 30,000 tons, a speed of 33 knots, an armament of four 5·1 in. guns and four 21·7 in. torpedo tubes. It will therefore be seen at once that the figures at our disposal do not bear out all the claims made in the report, showing clearly enough that the French constructors consider that some unrevealed details give their type of boat a superiority over their foreign rivals.

The armament of the six flotilla leaders, however, comes in for some criticism. It is proposed that they shall carry six 5 in. guns, and this the commission consider insufficient, as the Admiral Senes (ex German V 116) was armed with four 5·9 in. guns. The commission think that the matter should be reconsidered and armament of four, or even five, 5·5 in. guns of a light type is the "minimum admissible for flotilla leaders."

Expert opinion was very much divided upon the proposal to build large cruiser submarines: "Might not the 12,000 tons of the submarine cruisers be better utilised by building 12 boats of 1,000 tons or eight of 1,500 tons?" The commission none the less decided in favour of the submarine cruisers in order to have a division of three or four submarines working with the fleet, capable of firing salvoes of three torpedoes, and having a surface speed of 20 knots. The commission urged that the special vessels were an urgent necessity, but suggested that the minelayers and oil-carrying ships should be so designed that they might be used for transport in peace time.

The amendments answered by Monsieur Paul Denise's second report were: (1) that a hundred submarines should be built instead of 34; (2) that two instead of four cruiser submarines should be built and the 6,000 tons thus released devoted to submarines of between 1,300 tons and 600 tons; (3) that a submarine depot ship should be added to the programme. The commission rejected the first and third proposals and agreed to the second; seven minelaying submarines are to be built instead of the two cancelled submarine cruisers.

The second report contained the very important proposal to reduce the period of the second instalment of the building programme from six to four years and to complete it in 1928.

Year.	Cruisers.	Leaders.	Destroyers.	Cruiser Submarines.	Submarines.	Submarine Minelayers.	Miscellaneous.
1924	2	—	6	—	2	—	—
1925	—	5	6	1	7	2	1 minelayer; 2 oilers.
1926	2	5	6	1	7	2	—
1927	—	5	6	—	7	2	1 minelayer.
1928	2	—	—	—	7	1	2 oilers.
Total	6	15	24	2	30	7	—

The programme of ships to be laid down in the next five years, which the commission finally submitted to the Chamber of Deputies, is given in the Table above.

The most discerning criticism of this programme has come from outside the French Chamber. Towards the end of last year, Monsieur Laubeuf, whose name as a naval designer requires no introduction, read a paper before the Academie de la Marine entitled "Reflections on Naval Programmes." He contended, in the first place, that programmes must be made to correspond to certain specified strategical desiderata, which only the civil government could supply, as they only know what policy the fleet will have to support. In the second place, he argued that naval construction was, of necessity, so fluctuating that no government should commit itself to a programme of more than three years duration. Dealing next with the details of the draft naval bill, Monsieur Laubeuf pleaded for the suppression of the 10,000-ton cruisers. The first duty of the French navy would be to dominate the western Mediterranean; and the projected cruisers would in no way assist the fleet to do so. They were too large and costly to be used as fleet scouts, and far too weak to be treated as ships of the line. "No surface ship will be able to navigate the western Mediterranean if it is patrolled by strong forces of submarines and aeroplanes." Monsieur Laubeuf next criticised the French flotilla leaders. British leaders only displaced between 1,600 and 1,800 tons, and the American navy had no vessels of the type at all. The French displacement of 2,400 tons was, therefore, extravagant and unnecessary. In conclusion, Monsieur Laubeuf maintained that France only needed submarines of between 1,100 and 1,600 tons. Larger boats are only necessary to powers like Great Britain and America, whose navies had to act over very long lines of communications. France's navy will not have to operate outside Europe, so that, to her, the larger types of submarines are useless. Monsieur Laubeuf is very careful to show that his criticism of the programme must not be interpreted as a contribution to the capital ship controversy. He is only discussing France's immediate naval needs. "I do not deny that, later on, larger submarines may be necessary for operating against a distant enemy, or for protecting our outer colonies; and I admit that, later on, we may have to build battleships, battle cruisers, and other types of vessels."

THE CRYSTALLINE STRUCTURE OF ORGANIC SUBSTANCES.

AT the Royal Institution on Thursday, February 7, Sir W. H. Bragg, F.R.S., who has succeeded to the professorship held by the late Sir James Dewar, delivered the first of a course of four lectures on the above subject.

In commencing his discourse, Professor Bragg said that he had selected this theme because, although organic crystals were very, very complicated in shape and structure, it was possible by X-ray methods to determine from them some details, characteristic of all crystals, rather more readily than with simpler forms. He proposed in this course to deal with first principles, and would not assume that his hearers were acquainted with X-ray methods of analysis. Crystals, he continued, were combinations of atoms or molecules. Atoms might be regarded as analogous to an alphabet and molecules to the words formed by combining these. The number of letters in an alphabet was limited, but, unfortunately as some would say, the number of words was unlimited, and similarly we had a limited number of atoms and an unlimited number of molecules. A characteristic property of X-rays was that they enable us to determine the position of the atoms in a solid. In some crystals the atoms were arranged in a very complicated way, but the really astonishing fact was, that in so many cases they were arranged in such beautifully symmetrical forms. This was the case with crystals, and, reverting to the alphabetic and verbal analogy, crystals might be regarded as the poetry of molecular arrangements.

Let us consider, Sir William proceeded, what happened in the evaporation of brine when the salt began to be deposited. In that case some of the molecules first deposited, associated together in a certain definite way, and others arranged themselves on the nucleus thus formed, so that the structure was built up symmetrically finally becoming large enough to be visible. The result was a perfect regularity of arrangement based upon the structure of the molecule itself, on which the

symmetry of the crystal was in some way dependent. Crystalline form was, in fact, the outward and visible sign of some property of the molecules concerned. There must be something in these to account for the cubic symmetry of quartz, the hexagonal crystals formed by other bodies, and the long needle-like crystals characteristic of certain organic compounds.

A good analogy to crystal building was afforded by a piece of ornamental knitting, where certain stitches were formed in a special way to form the unit of the pattern, and these units were repeated again and again. Similarly, nature took for her unit in crystal building two or three, or four or six units, and each such unit when formed was repeated. The process took place in three dimensions, and hence if planes were drawn through a corresponding point of each of these units, these planes would intersect in systems of parallel lines, which were known as the space lattice of the crystal. No matter how complicated the pattern might be, its repetition yielded always these simple space lattices. Such a system, Professor Bragg continued, was represented in Fig. 1, where it would be seen that each cell in the whole structure had the same content, and at each intersection there was a certain definite atomic grouping. What we desired to know was how the atoms and molecules associated with such space lattices were put together, and what was the size of the individual cells. This was commonly expressed in the Angström unit of 10^{-8} cm. In the case of napthalene it had been shown that the cells out of which the crystal was built up contained two molecules each, and the crystal was produced by repeating this unit pair again and again. Until the invention of X-ray methods of crystal analysis, it was impossible to say either how many molecules were in each cell or to measure the size of this cell. By using X-rays, however, we could now find the distances between the walls of the cells, and could then calculate from the known density of the material the quantity of matter contained in each cell, and then, on dividing this by the weight of one molecule, we got the number of molecules in each unit cell. In the case of napthalene, this turned out to be two, as already stated.

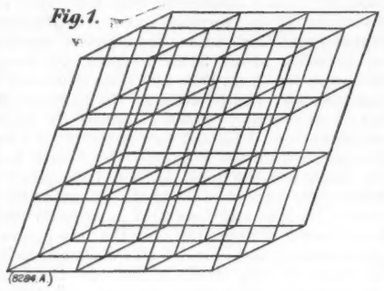
We also wanted to know the shape of the napthalene molecule and what points of it were in contact with other molecules. In this direction much remained to be done, but the X-ray methods had given us very definitely the size of the cell.

X-rays, Sir William proceeded, were a form of light characterised by an extremely short wave length. The rays commonly used for crystal analysis had a wave length of from ½ to 1½ Angström units. It was necessary to use homogeneous pencils of rays, such as the characteristic radiation of different atoms. Those from molybdenum, having a wave length of 0·7 Angström units, were very largely employed.

When X-rays fell on a crystal they were not reflected by the surface, which might in fact be rough, but they passed into the body of the crystal, where they encountered successive parallel layers of molecules. From each layer a very small fraction of the incident radiation was reflected, but the bulk of it passed on, the phenomena being closely analogous to what occurred when ordinary light was passed through a succession of parallel sheets of glass. In the case of the X-rays, reflection occurred only at the points occupied by atoms, but if these were regularly arranged in a plane, reflection occurred just as happened when sound was reflected from a row of palings.

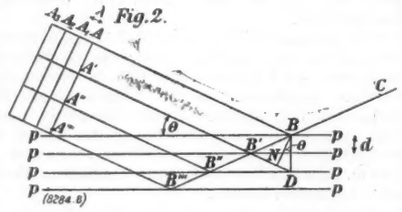
Suppose the lines A A^1, A^2 and A^3 (Fig. 2) represented successive waves of X-rays falling on a crystal of which one system of space lattices was represented by the horizontal lines. At each of these horizontal planes a little of the incident radiation was reflected. The ray which fell on B was sent off along the line BC. Reflection along the same direction also occurred at B′, B″, B‴, and so on. Since there were thousands and thousands of layers, and each sheet acted as a feeble mirror, the total quantity reflected was large. Whether the resultant reflection was strong or evanescent depended upon whether these successive reflections along BC were, or were not, in phase, crest to crest and hollow to hollow. If the successive reflections were in phase, a strong resultant reflection would be secured, but if under these conditions the crystal were given the slightest tilt, then the waves reflected from the successive layers would interfere and destroy each other. Hence, to secure a strong reflected beam, it was necessary to have a certain definite relationship between the wave length λ of the incident rays, the distance apart of the planes *pp* and the angle θ. Unless this angle was exactly right there would be no reflected beam. This might appear strange, since an ordinary mirror reflected light incident at all angles, but this was not the case with X-rays. Hence when the X-ray reflections flashed out, it indicated that there was a certain definite relationship between the lattice spacing, the wave length, and the angle of incidence.

Fig. 1.



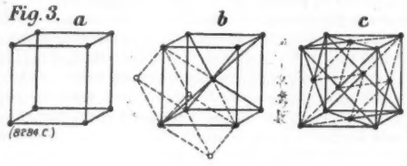
(8284 A.)

Fig. 2.



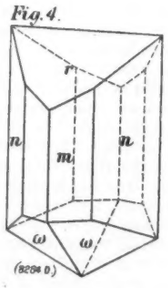
(8284 B.)

Fig. 3. *a* *b* *c*



(8284 C.)

Fig. 4.



(8284 D.)

It followed, therefore, that with different space lattices and a given value of the wave length λ, a different angle of tilt was required to secure reflection.

It was by taking advantage of this fact that the distances between the different space lattices of a crystal had been measured, and this done, we could map out the position of all the constituent units of the crystal. In the case of aluminium, copper, silver and gold, it turned out that the atoms were arranged like piles of shot, and the distances between neighbouring atoms had been measured from the known wave length of the X-rays used.

An important point that arose was the number of different ways in which we could regularly array atoms in space. This number was not infinite, as might possibly have been anticipated, but some 30 years ago three independent writers showed that the possible number of different regular arrays was 230. This conclusion was established by purely mathematical considerations, but it turned out that many of these possible arrangements led to the same outer crystalline form, and crystals had been classified accordingly. Each class, however, included a number of the 230 different arrays; in one case as many as 28, and until the invention of X-ray analysis it was not possible to distinguish any difference in the arrangement of the constituent units of crystals belonging to the same class.

The units constituting the cells differed widely in symmetry. In some cases, as with certain dye-stuffs, none of the sides of the cell were equal and none of the angles right angles. A more symmetrical cell was square in one presentation, but in another the sides, though all equal, made angles of 60 deg. and 120 deg. with each other. Such a cell had, however, a plane of symmetry, and with crystals built up of such constituents we got certain of the units forming squares, and before the development of X-ray methods such crystals were classed as ordinary cubic crystals. The most symmetrical cell was a cube such as was represented at *a* in Fig. 3. Here all the sides were equal and all the angles right angles. On the other hand, the cubic forms shown at *b* and *c* having in the one case an atom at the centre of the cube and in the other atoms at the middle of each face, were built up of the unit cells indicated by the dotted lines, which were not cubes, although the resultant crystal was cubic and all looked alike in outward form.

As already stated, each class into which the 230 possible arrays were divided consisted of crystals that looked alike and of which the structure could not be differentiated without the aid of X-ray analysis. There was, however, one point in which X-ray methods failed. Some molecules had polar properties and crystals built up from them had different properties on opposite faces. Since the X-rays measured merely the distances between the space lattices, they provided no information as to whether the units found had, or had not, these polar properties. This could, however, generally be settled in other ways. An example of a crystal thus constituted was represented in Fig. 4, where it would be seen that the shape at the bottom differed from that at the top, and the two surfaces had also different electrical properties.

THE PHYSICIST IN METALLURGY.

"Although every worker of metals from the earliest times has more or less unconsciously applied physical principles, and although physics is historically an older science than chemistry, the conscious application of physical laws and methods to the practice of metallurgy is quite recent, more recent even than the control of metallurgical processes by the chemist. At present a sound knowledge of physics is as essential to a trained metallurgist as a knowledge of chemistry. The art of handling instruments is sooner acquired, but in progressive works new problems present themselves daily to the worker who has the spirit of research, though they may have no existence for the unimaginative or scientific mind, a type unfortunately too common in industry."

With these words Professor Cecil H. Desch, F.R.S., introduced his lecture on "The Physicist in Metallurgy," delivered on February 6 before the Institute of Physics. He proceeded to specify his plea for the physicist which does not require any general emphasis in our days of the physical —no longer chemical—atom. The rapid progress of the engineering and electrical industries, he pointed out, called for metals and alloys combining the most manifold properties with the former chief requisite, mechanical strength. Fortunately the laboratories of the leading firms were fully equipped with pyrometers, electric, magnetic and general measuring instruments; but the task of the metallurgical physicist began already in the mine. To the ore separation by jigs, concentrating tables and magnetic and electric apparatus, had been added separation by the ore flotation method, by which some 70,000,000 tons of ores, mostly low grade, were now treated annually. The theory of ore flotation was imperfect, since the surface tension at a solid/liquid boundary was not easily determined, and it was noteworthy that fresh surfaces of fracture

behaved differently from old surfaces on exposure to air and reagents.

For the strict control of thermal treatment the thermocouple was very convenient, though the resistance thermometer had advantages for taking continuous records of furnace temperatures. For temperatures above those borne by wires, optical radiation pyrometers, perferably monochromatic instruments, were available. Useful in skilled hands, pyrometers were dangerous when used with insufficient understanding. The old tool-hardener could judge temperature with an almost uncanny accuracy, while his successor, probably his inferior in craftmanship, would altogether rely on a pyrometer, possibly in error or not set at the proper place. A forging inside a uniformly-heated furnace, observed through a small hole in the door, would fulfil the black-body condition; but when the pyrometer was directed towards an ingot passing through the rolls, where it was at one moment bare and at the next covered with an oxide scale of entirely different emissive power, most misleading results would be obtained. Professor Desch had actually been told that the blocks became hotter while under the roll, pyrometer readings having been misunderstood.

Passing to ferromagnetism and its changes with temperatures, Professor Desch mentioned the Japanese "carbometer," an instrument for the rapid estimation of the quantity of carbon in a furnace bath; a slender bar of the steel was cast in an iron mould and successively magnetised and demagnetised. In America steel rails were tested for transverse internal cracks—which seemed to be more common there than over here—by pushing a solenoid coil over the rail and tracing a magnetisation curve; flaws in wires were similarly detected. In exemplification of the imperfection of the theory of magnetism, Dr. Desch referred to three technical alloys. The Heusler alloys (1898), as magnetic as cast iron, consisted of three very feebly magnetic metals (copper, aluminium, manganese). The alloys of nickel and iron lost their magnetism when the nickel contents exceeded 20 per cent.; yet an alloy of 78·5 per cent. of nickel had an extraordinarily high magnetic susceptibility, which could not be explained by the constitution; though this "permalloy" was magnetically saturated already in the field of the earth, the high permeability was utilised in cable work. On the other hand, 40 per cent. of cobalt (replaceable by the cheaper chromium imparted to steel a surprisingly high coercive force. None of these three effects could have been predicted.

When Professor Whiddington described his ultra-micrometer before the British Association at Edinburgh in 1922, the fear was expressed that the instrument would prove too sensitive. Dr. Desch mentioned that Mr. Cecil Handford was, in his laboratory, determining the load required to produce the first slip on crystal planes in a metallic test piece; the earliest slip planes always evaded microscopic detection. In applying the Whiddington method the polished specimen was mounted vertically and a thin sheet of mica was clamped on to it by means of a brass block, the arrangement constituting an electric condenser, which was coupled up in a valve-circuit for heterodyne telephone-reception. When tension was applied to the test piece, incipient plastic slip caused a minute ruffling of the surface, the mica was thrust away, and the capacity of the condenser was diminished; the observer listening on the telephone thus heard an altered note as soon as the limit of elastic expansion was exceeded. Proceeding, Professor Desch stated that electronic studies and the X-ray study of stress-strain problems justified hopes of our understanding the nature of cohesion and its "directed" quality. Dr. A. Griffiths had obtained silica glass of the calculated theoretical cohesive strength far in excess of that found in ordinary practice, and Dr. Rosenhain had in his Sorby lecture made that fact the basis of a vision of future metals of enormous mechanical strength; whether such a structure could be rendered stable was an attractive problem for the future.

The question as to which of the allotropic modifications of iron was present in hardened steel had been settled by the X-ray experiments of Westgren, which showed clearly that the a space lattice was present there, as in the slowly-cooled steel, so that the increased hardness could only be due to the carbon atoms producing distortion of the lattice. In a similar way Owen and Preston had, at the National Physical Laboratory, disproved the supposed resolution of the β solid solution in brasses into two constituents on cooling, as to which thermal and microscopic evidence was conflicting. Professor Carpenter and Miss Elam had obtained single crystals of large size by straining pure aluminium to a certain critical extent and then annealing the specimen; and Professor G. I. Taylor had quantitatively studied the nature of the deformation of a single crystal. Dr. Desch explained these features by exhibiting the diagrams of Polanyi on experiments made with single crystals of zinc, in which slip was almost entirely limited to the basal plane of the hexagonal crystal.

Large crystals of lead, *e.g.*, were also obtained by introducing a nucleus of the metal into the molten lead and raising the crystal at a rate just equal to the velocity of crystallisation. In tungsten filaments large grain crystals, extending over the whole cross-section, were undesirable because "offsetting" and breakage might occur. To avoid that either some mechanical obstacle, such as powdered thoria, was interposed, so that the metal grains remained fine, or the whole wire was—over a length of possibly a quarter mile—converted by thermal treatment into a single crystal, devoid of any grain. Single crystals, even of zinc, which was very brittle as a grain aggregate, were very ductile, and such tungsten wires after working were valuable as suspension wires. The elimination of the puzzling factor in scientific metallurgy, the inter-crystalline boundary, might lead to important results.

For the preparation of the materials tested the high-frequency induction electric furnace, especially when vacuum working was required, had great advantages, not only in the laboratory. The iron placed in a crucible, within a silica cylinder, would melt before the silica looked hot; pure iron thus prepared, Professor Carpenter subsequently remarked, might prove to be a practically-new metal. Of recent applications of optical methods Dr. Desch only mentioned the resolution of fine surface details by means of illumination by polarised light, and the study of grinding and polishing and of tarnishing by the determination of the reflective power of the surfaces.

In his concluding remarks Professor Desch referred to the important educational aspect of the subject. The university graduate would at first feel lost in metallurgical works; Professor Desch had found that the ideal university training for such purposes was a degree course in pure science, followed by a shorter specialised course in metallurgy. Indispensable for the scientist was further the breadth of mind required to appreciate the difficulties of the experienced, though not scientifically-trained, practical man; the two had to co-operate on terms of mutual respect.

Before calling upon Dr. Eccles to propose a vote of thanks to the lecturer—which was supported by Professor H. C. H. Carpenter—Sir Charles Parsons, President of the Institute of Physics, made two remarks regarding the heat treatment of steel. It had, apparently, been overlooked that the stresses and strains induced by rapidly heating up or cooling were much greater in the case of large masses of metal than in small masses. Thus when a large mass was suddenly placed in a hot furnace or when it was oil-quenched, the difference in temperature between the outside and inside might be many hundred degrees C., and many failures of gear teeth on board ship had been traced to the latter cause, while several rejections and failures of large turbine shafts had been attributed to unduly rapid heating. Small shafts or gears for motor-cars might be treated with safety; it was a question primarily for the physicist and, secondarily, for the metallurgist. Such failures had fortunately been rare on the whole, and very few indeed had caused loss of life; yet the cause was unmistakable.

"VIBRATION AND STRUCTURAL DAMAGE."—In the article published under this title on page 163 of our issue of February 8 we regret that by a printer's error the third and fourth photographs were inverted. The mistake would not, we think, cause any misunderstanding to readers of the article, but in fairness to the author we take this opportunity of correcting it.

NOTES.

MANCHESTER ASSOCIATION OF ENGINEERS.

IN proposing the toast of the Manchester Association of Engineers at the annual dinner held in the Midland Hotel, Manchester, on Friday, February 8, Sir Max Muspratt, Bart., expressed the opinion that too great specialisation in industry was liable to cramp the outlook of the individual and detach workers in the same field from each other and make them unfit to deal with the great problems of the present time in a broad way. Successful work could only be accomplished by co-operation between the separate interests. Without it the pooling of experience in a satisfactory way was impossible, and the industry concerned suffered in consequence. In his reply the President of the Association, Mr. Cecil Bentham, took the example of the many Institutions meeting in Manchester, and referred to the happy way in which they were able to co-operate with one another. Much adverse criticism had been made in some quarters of the extension of the activities of some of the Institutions by the formation of local sections. This growth was not to be looked at in any critical spirit, for they had found, as the result of experience, that the increase in the number of societies holding meetings in the town had been of great benefit to the profession. Some engineers were on the councils of two or more of these societies and were able to exert their influence in preventing the clashing of subjects discussed by the societies and in arranging that the work of each was complementary to the others. While this attitude prevailed nothing but good could result from an extension of the activities of any engineering Institution by the formation of a local section in the district.

THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS.

At the annual general meeting of this Institution, held on Monday last at the Holborn Restaurant, W.C., Mr. P. M. B. Grenville, who was appointed President for the ensuing year, delivered an address in which he called attention to the desirability of including younger men on the Council and on the various committees. He also suggested the formation of provincial branches of the Institution and the establishment of a bureau of information for the use of members. Reference was also made in the address to the work of the research committees of the Institution, and the President appealed for further financial support for these committees, so that their work might be continued without intermission. At a later stage, an address was delivered by Sir George Croydon Marks, M.P., and in the evening the annual dinner was held—also at the Holborn Restaurant. In responding to a toast proposed by Mr. J. Watson, the President referred to the development of the Institution during the 27 years it has been in existence, and also emphasised the main points of his address mentioned above. Mr. G. Copping, in proposing the toast of the Institution, said he would like to see a larger proportion of foreign members, and also expressed the view that the scope of the Institution's work with respect to ventilation should be widened to embrace such matters as the drying of timber and other materials, air supply to furnaces of all kinds, and air conditioning processes such as those employed for controlling the humidity in weaving sheds. In responding to this toast, Mr. E. Herring, who is chairman of the Research Committee, referred to the value of the research work being carried on at the University College, and appealed to the members to show their appreciation of the work by occasionally visiting the College. Such visits, he said, would greatly encourage the research workers. The dinner, which was attended by about 80 members and visitors, was a highly successful function and the secretary, Mr. W. G. Hollingworth, is to be congratulated upon the arrangements. The offices of the Institution are at 38, Victoria Street, Westminster, London.

OIL-FUEL INSTALLATIONS ON PASSENGER STEAMERS.

A new circular containing instructions to surveyors with regard to oil-fuel installations on passenger steamers has just been issued by the Marine

Department of the Board of Trade. This circular, which bears the number 1647, is mainly a reprint of one numbered 1624 and issued in November, 1920. The new publication, however, contains a number of additional recommendations which have been included as a result of experience gained during the last few years, and which have already been adopted in many installations. One of the recommendations refers to the fitting of relief valves on oil-filling lines to prevent the latter from being subjected to undue pressure by the closing of a tank-filling valve while the filling pump is at work and before another tank valve has been opened. The importance of this provision is not always realised, and cases are on record in which serious leakage from the joints, resulting in destructive fires, has occurred in the absence of proper relief arrangements. Another recommendation relates to short sounding pipes to oil tanks situated below machinery spaces, and is to the effect that the use of such pipes should be avoided as far as possible. If they are employed, and when they terminate in a stokehold, they should be arranged so that oil will not be discharged on to any part of the boilers or fittings if the self-closing cocks at the upper ends of the pipes are opened when oil is surging in the tanks due to the motion of the ship. Master valves at the furnace fronts should be readily accessible in emergency, and should be of the quick-closing type. Sectional shut-off valves should also be arranged to isolate air vessels in order to prevent the discharge of any oil they may contain in the event of any derangement at the furnace fronts. In connection with the changing of burners, it is recommended that arrangements should be made so that the oil cannot be turned on to a burner unless the connections have been correctly made. This provision is certainly necessary, as several fires have occurred owing to the escape of heated oil in cases where burners have not been properly replaced. With regard to fire prevention, the recommendations state that fire-service pumps should not all be situated in one space, and that steam supplied to perforated pipes in stokeholds for fire-extinguishing purposes should be at the full boiler pressure. The use of froth or foam for fire-extinguishing purposes is strongly recommended, as also is the provision of an adequate number of hand extinguishers of this type for rapid use in emergency. Several other points are dealt with in the circular, which is published by H.M. Stationery Office and is obtainable, either directly or through any bookseller, price 2*d.* net.

CLASSES IN DOMESTIC ENGINEERING.

With a view to improving the status and increasing the technical knowledge of those engaged in the heating and ventilating trades, the National Joint Industrial Council for this industry are endeavouring to arrange for the establishment of complete courses of study at various educational centres. They also hold that indentures of apprenticeship should provide for the regular attendance of the apprentice at appropriate evening classes. The course of study, they recommend, should extend over six years. The junior course will be suitable for boys leaving the public elementary schools at the age of 14, and will deal with elementary physics and mathematics, including in the latter the uses of squared paper. The senior course, which may be taken forthwith by those who have already received at school an adequate grounding in the elements of the sciences above named, will be somewhat more advanced. Both these courses are non-specialised and are covered by the evening class curriculum at all centres for technical education. It is, however, desired to provide a further special course, extending, like the preceding, over a period of two years, for those who, having attained the standard required in the senior course, wish to study more exhaustively the technics of domestic engineering. This course will in most cases involve the formation of new classes, as this subject is not adequately catered for in the curriculum of most technical schools. It is hoped that the need may be met, but the authorities concerned require in each case a minimum of 12 students. The scheme above outlined will require attendance at evening classes for six hours per week, and there will be home work in addition. One difficulty foreseen is involved in the fact that class work may be interrupted by students having to leave home on erection work. It is hoped, however, to minimise the loss thus arising by means of correspondence. Another difficulty, which, however, will automatically tend to disappear with lapse of time, is that at, even the elementary classes, there will be great differences in the ages of the students; but it is felt to be impracticable to make special provision for the adults, who now realise the drawbacks appertaining to their ignorance of elementary scientific principles and facts. So far seven centres have been formed in London and the provinces. As already indicated, the courses above described are intended for evening students, but the Joint Industrial Council also realise the advantages of day classes, and are promoting a movement to secure during the winter months one day a week in the technical school for students up to 18 years of age. This proposal has the approval of the council of the employers' association. Further details can be obtained at the offices of the Heating and Domestic Engineers, National Joint Industrial Council, 38, Victoria-street, London, S.W.1.

ENGINEERING IN LIVERPOOL.

Although Liverpool is not concerned to any great extent with engineering manufacture, it is none the less a town of great importance to engineers in view of the engineering side of its shipping industry and of the docks and other great engineering public works which it contains. Liverpool is still the only provincial town in the country in which suburban railway electrification has extended to more than one line, while its overhead railway is the only example of such a structure which we have. A rallying point for the many and varied engineering interests of the town is furnished by the Liverpool Engineering Society, which this year reaches the fiftieth anniversary of its foundation, and that the Society is in a flourishing condition was amply demonstrated at the annual dinner which took place at the Midland Adelphi Hotel on the 7th inst. The chair was taken by Mr. J. A. Brodie, past president of the Institution of Civil Engineers, and president of the society, and in responding to the toast of the "Liverpool Engineering Society," which was proposed by Mr. Stuart Deacon, Mr. Brodie incidentally illustrated some of the more recent engineering interests of the town. He referred more particularly to the various great road works with which his own name has been so closely associated and to the proposed road tunnel under the Mersey. The chief other speech of engineering interest was contributed by Sir John Aspinall, who proposed the toast of the "City of Liverpool." Sir John referred particularly to the foundation of the Harrison-Hughes Laboratory of Engineering at the University of Liverpool. This laboratory was founded by various members of the well-known shipping firm of Messrs. T. & J. Harrison, we believe, in the late 'eighties, and it was of great interest to hear from Sir John, who at that time was chairman of the Faculty of Engineering, that Mr. Hughes, one of the founders, stated that he trusted the laboratory would do work which would forward the use of the internal-combustion engine for marine work. He believed the engine was going to do a great deal for shipowners. In view of the developments of the present day, this opinion showed remarkable prescience. The shipbuilding industry of the Mersey has done its share towards the advance which has taken place, while the Liverpool Engineering Society, so many of whose members are concerned with operating rather than manufacturing, must form an important influence in the education of shipowners to the possibility of modern engineering methods. The society, which now has a membership of 850, must ever find new matter to deal with in the engineering development of the great port with which it is associated, and if the annual dinner may be taken as an indication the society is in full tide of prosperity. The council and the hon. secretary, Mr. G. Kenyon Bell, are to be congratulated on the very great success of that function.

ELECTRICITY ON OIL FIELDS.

The electric motor, despite its numerous and valuable qualifications, has had difficulty in making a place for itself in some spheres of activity. This has particularly been the case when conditions have been such that excessive overloads may, with little or no notice, be thrown on the machine which is being driven. For conditions of this kind, the qualifications of the steam engine are particularly well fitted, since if the overload becomes too great the engine merely stops, but continues to exert its full force, ready to start again the moment conditions become a little easier. These characteristics can hardly be reproduced by an electric motor, with which excessive overload usually means the opening of a circuit-breaker. The advantages of electric driving in the way of economy, and the concentration of the generation of power, are so great, however, that there is always much inducement to consider the possibility of its introduction, and in a paper read before the Institution of Petroleum Technologists on Tuesday, Mr. C. H. McCarthy-Jones gave some details of the very considerable success which has attended the introduction of electric driving on the Yenangyoung Field of the Burmah Oil Company. The usual method is to employ isolated oil-fired steam plants at each well for drilling and pumping, but by introducing a central power station with overhead distribution and motor drives at the wells very striking economies have been effected. For a well 2,165 ft. deep, Mr. McCarthy Jones gave the cost of power for drilling at 181*l.* with the electric drive, and 550*l.* with a steam plant. Other wells gave comparable figures. For pumping the relative figures were 12*l.* 10*s.* per month with electric driving, and 45*l.* a month with isolated steam plants. Special motors have had to be developed for the work, and various modifications and improvements have been introduced over a number of years. The motors must be very robust and of exceptional overload capacity, and for percussive drilling must have a free-fall characteristic on the downward stroke so as to utilise the stretch of the cable in the manner distinctive of an effective percussive blow. Wide and close speed regulation is also necessary. Alternating current slip-ring motors are almost universally employed for the work, and the speed regulation is effected by two controllers, one supplying the coarse regulation and the other the fine. In this way about 80 different running speeds are obtained. A motor of about 75 h.p. is employed either for percussive or rotary drilling. Pumping appears at first sight a simpler problem than drilling from the motor point of view, but considerable development work has been necessary owing to the oil-field practice of using the pumping motor for pulling the rods and tubing and at times for light redrilling work. The most successful arrangement has proved to be a two-speed motor with a change-over switch so that it can run at low speed and small output for ordinary pumping duty and at high speed and high output for other work. Considerable speed regulation is provided at either speed. The most suitable size of motor has proved to be one giving 12 h.p. to 15 h.p. at the low speed and 30 h.p. at the high.

THE INSTITUTE OF METALS.—The annual general meeting of the Institute of Metals will be held at the Institution of Mechanical Engineers, Storey's-gate, Westminster, on Wednesday and Thursday, March 12 and 13, commencing each day at 10.30 a.m. The Presidential Address will be delivered by Professor T. Turner, M.Sc., A.R.S.M., in the morning of March 12. No fewer than 14 communications are due for presentation and discussion at the meeting. The annual dinner of the Institute will be held at the Trocadero Restaurant on Wednesday, March 12. It is of interest to note that the membership passed the 1,500 mark on December 31, 1923.

THE TAXATION OF MOTOR VEHICLES.—From statistics recently issued by the Ministry of Transport, we gather that the gross receipts from the taxation of motor vehicles, &c., in this country during the year ended on November 30 last amounted to 13,313,334*l.*, this figure being subject to some adjustment with respect to refunds. Excluding tramcars and trade licences, the total number of motor vehicles for which licences were current on November 30, 1923, was about 1,066,000, including, in round numbers, 383,000 cars taxed on a horse-power basis, 391,000 motor-cycles, 181,000 commercial goods vehicles, and 78,000 hackney carriages. The revenue from these four classes of vehicles was 5,875,000*l.*, 1,087,000*l.*, 3,703,000*l.*, and 1,915,000*l.*, respectively, and the average payment on a whole year's licence in each respective class was 16*l.* 18*s.* 6*d.*, 20*l.* 11*s.* 6*d.*, 21*l.* 7*s.*, and 25*l.* 11*s.* 6*d.* Horse-drawn vehicles, of which some 215,000 were licensed on November 30 last, contributed only 167,000*l.* to the above-mentioned total.

LITERATURE.

The World-Struggle for Oil. By PIERRE L'ESPAGNOL DE LA TRAMERYE. Translated from the French by C. LEONARD LEESE. London: George Allen and Unwin [Price 8s. 6d. net.]

"JUST as the British Empire was built upon coal-fields, so the empires of the future will be founded upon the possession of oil." This sentence, which the author places conspicuously on the covering of his book, and apparently regards as an unquestioned axiom, will be regarded by some as an unwarranted and premature conclusion. Fifty or sixty years ago, the prominence of petroleum in the industrial and military world was not foreseen, and it is quite conceivable that with advancing knowledge, other and now unsuspected sources of power will displace mineral oil from its proud position, as the rushlight or the windmill has been displaced by more convenient or efficient agents. But nations and governments cannot pause to wait the advent of some new thought, the development of progressive science. They must use the means at present available, and oil, enjoying for the moment great opportunities for the furtherance of industry, is eagerly sought by those countries who are deficient in the commodity, and as willingly sold by those who have it in abundance. It is the history of the struggle between the purchasers and the possessors that the author endeavours to tell. He describes the tactics and policy of the contracting parties but not without a certain amount of peevishness and disapproval of the results attained. There is perhaps no direct charge against the honour and honesty of the English agents, though it is implied that these are masters of subterfuge and disingenuousness. A tone of displeasure is exhibited whenever the foresight and alertness of the English have enabled them to carry their enterprise to a successful issue. M. de la Tramerye has little indulgence for that sense of self-interest, implanted in both individuals and nations, which leads every man or community to fight against the hostile factors that are conceived to be prejudicial to the general welfare, and to strive for those that are likely to prove an advantage in the struggle for existence.

The book might serve as an illuminating history of the development of trusts and monopolies, but to be of value one must be assured of the accuracy of the statements, and be convinced of the absence of bias. One misses the evidence of accuracy or of careful sifting of evidence. Able financiers have been at pains to conceal their manœuvres, to give false clues, or allowed misrepresentation to pass without contradiction. The effect is too often to make the obvious construction misleading and deceptive. No doubt the author can find some kind of support for every item given, and every inference drawn, but it is not possible to gauge the trustworthiness of the evidence for want of sufficient reference to authoritative documents. Perhaps, too, distrust is awakened by the failure of results to follow the lines indicated as a consequence of the policy pursued by the oil magnates and the governments who are represented as supporting their schemes and directing their efforts. The contents of the volume have not been brought very closely to date; indeed, very few facts are given later than 1921, and therefore it is possible to compare the results anticipated by the author with the facts as they have developed. We are led to expect that the United States output of oil would be curtailed to such an extent that serious difficulty would be encountered in satisfying demand. M. de la Tramerye writes: "If the United States do not succeed in acquiring new oil-fields in the rest of the world, the position will become so serious that they will only be able to avoid war at the price of economic vassalage." This remark is not warranted. The home resources have proved more than sufficient. The market has never been more amply supplied, while Mexico, who was regarded as the buttress of the oil world, has, judging by the market quotation of her principal oil shares, lost her high estate.

The evidence of bias directed against this country is easily perceived. We are told that Great Britain, in order to maintain her world supremacy, resolved to win the control of oil, as she had done with coal. With this view technical experts and diplomatists joined their forces. "They laid their plans and followed them for years with determination. They sank millions of money and carried on intrigues in every corner of the world. They fomented revolutions and accumulated on their own shoulders responsibilities, risks and expenses." As a consequence, we are represented as taking part in the Mexican struggle, backing Porfirio Diaz against Madero, and taking an active part in later *emeutes* and revolutions. Costa Rica did not escape our evil machinations, "for Great Britain did not scruple to foment revolution in this little Republic." Those who credit these rash assertions will readily believe that British companies, organised by the British Government, are now in exclusive possession of 90-97 per cent. of the future world production.

The tale the author had to unfold was one of dramatic interest, but we fear he has missed his opportunity by crediting too readily the reports and assertions that interested parties have made current. The growth of the Standard Oil Company is one of the romances of industry. Its progress in influence and wealth has been as phenomenal as it has been rapid. Its success has won for it many rivals, who have imitated and profited by its methods and extended its policy. The main struggle has been between giants, on the one side the Standard Oil Company, engineered by Rockefeller and his associates; on the other, the Royal Dutch Shell, with its many tentacles, operated and controlled by Henry Deterding. With whom the victory will finally rest is doubtful, and we cannot rely very confidently on the author's conclusions. He intimates that the Standard Company has been outwitted and overthrown, but we doubt if the competition and enterprise of rival combinations have done more than delay the rapid increase in control, which marked the early days of the original company. We believe, however, that the author is justified in contending that from the point of view of their own aggrandisement the American managers pursued a too domestic policy, and limited their energies too strictly to their own Continent: a sufficiently large field for conquest, no doubt, but Deterding aimed at a world monopoly by firmly establishing an offshoot of his company wherever oil could be collected. To dominate the production and sale in America was a sound policy while the United States owned the world's oil, but the Royal Dutch, by breaking down the monopoly, could virtually limit the field in which American enterprise worked. But the end of Standard oil and of American production is not yet, though some authorities have predicted the exhaustion of the oil-fields in sixteen to eighteen years' time.

Already have been given some instances to show that M. de la Tramerye regards with a jaundiced eye the efforts of the English Government to protect its interests in the race for oil. This attitude is more particularly noticeable in the chapters on a State Standardised Company, the Anglo-Persian, and in the discussion of international relations and treaty obligations. There is no necessity to return to a subject that has been made unsavoury by its method of presentation, but in conclusion a word should be said of the author's opinion of the tactics pursued by the French politicians. He seems to wish to represent the French as following an unselfish, self-denying policy that has not brought an adequate reward. "France," he says or sighs, "often points the way to progress: she never profits by it." His own account shows that France has never exhibited any earnest enterprise in the matter of exploiting petroleum. The history of the industry is traced since 1870, and it is obvious that the distribution has been ruled by a cartel of ten firms, who have manœuvred the co-operative sale of their product for their own benefit, and that of the Standard Oil Company. There was, and could be, no healthy competition. The cartel were simply Rockefeller's representatives in France, his oil exporters. The prices at which each of the combine should sell were fixed weekly, and the ten firms signed an undertaking to sell at the prices fixed. The consequence was that the industry was atrophied, it never got out of leading strings, and was incapable of initiative. During the war, the cartel system failed, and the managers had to confess their impotence and resign to the State a task for which they were utterly unqualified. After the war, accustomed to a state of tutelage, the French appeared willing to create Franco-British companies, under the ægis of the Royal Dutch and Anglo-Persian Companies, who apparently offered more favourable terms than did the Standard Oil. This action is represented as a determined effort to keep out American oil, just as the attempt to prospect for oil in Algeria is represented as an attempt on the part of England to rob France of her petroliferous deposits. The San Remo agreement and the long stretched-out diplomatic negotiations form another grievance, in which France is represented as reaping the enmity of the United States by her subservience to British policy. No doubt, M. de la Tramerye feels sore, but we cannot see that we are to blame for his soreness, and we think that he is not warranted in his despairing cry that if France "had to defend herself against a fresh attack, her tanks, her aeroplanes, her submarines, could only function by consent of her Allies."

Materials and their Application to Engineering Design. By E. A. ALLCUT and E. MILLER. London: Charles Griffin and Co., Limited, 1923. [Price 32s. net.]

IN the past almost every industry has been practised essentially as an art, although it may, and probably did, originate in the truly scientific insight of some highly intelligent observer, whose very name has long passed into oblivion. Subsequent developments may also have had a rational basis when first introduced, but this was, for the most part, soon forgotten, and successful methods and processes were passed on from generation to generation simply as workshop recipes, forming part of the "mystery" of the craft into which it was the master's duty to initiate his apprentices. A collection of trade secrets is, however, of interest and value merely to those actually engaged in the calling. If, however, these maxims and precepts can be rationalised and systematised appeal is made to a much wider circle, constituted in part by an ardent few afflicted or endowed with more than the average of curiosity, but in much the larger proportion by those who, having to utilise the products of the industry concerned, find that some knowledge both of its possibilities and its limitations may at times prove of very great service.

Until quite recently metallurgy had, in some very important directions, hardly emerged from the status of an art. Perhaps it will never be wholly reduced to a science, but the studies of the past thirty years have thrown a great deal of light upon matters which our predecessors had to accept as riddles without an answer. Owing to the progress made in elucidating and systematising metallurgical facts, it is less hopeless than formerly for an engineer practising in other fields to acquire some knowledge of metallurgical principles and processes. He can now learn to recognise the principal constituents in micrographic sections of steels and alloys, and can picture the actual physical character of the changes brought about by heat treatments.

Those engineers who desire to acquire knowledge of this kind will find their requirements excellently met by the work under review, although such of them who are mainly concerned with structural material may quite possibly take exception to some of the *obiter dicta* of the authors on purely engineering questions. The practical experience of the authors has, apparently, been gained mainly in the construction of engines for aircraft. Here great use is made of alloy steels, many of which differ markedly in their physical properties from the qualities in common use. Stresses are severe and are largely alternating in character, and consequently conclusions founded on experience thus gained cannot be held as universally applicable. Hence the authors' criticism of the basing of factors of safety on the breaking strength will be questioned by many, as will also the further statement that "If the stress in any detail exceeds the elastic limit, there will be a certain amount of permanent stretching with each application of the load. This will ultimately result in the failure of the detail." This contention involves the assumption that the elastic limit is fixed, whereas the application of an excessive stress raises it, and thus bars subjected to a non-alternating stress may in many cases be safely stressed beyond their original elastic

limits. The competent engineer will, of course, be guided in these matters by his own experience, but on metallurgical questions he will find the authors clear and sufficiently comprehensive.

The section on the micro-structure of materials will prove particularly useful. It contains a pretty full discussion of the constitutional changes occurring in steel as it is cooled from the melting-point down to room temperatures. In their discussion of heat treatment the authors revive the long-standing controversy between the steel-maker and steel-user. It is stated that the varying results obtained in many hardening shops arise from the treatment the steel has received before purchase, and are not due to lack of skill on the part of the operative. No doubt those who supplied the material will maintain the contrary, and it is here that micrography may prove of very material value commercially. It is not, however, always the maker that is guilty of ignoring the need for uniformity. Drop-stampers and drop-forgers are said to be the greatest offenders in maltreating steel. They are prone both to overheat the material and to heat it unequally. An interesting micrograph is given showing how a large nickel-steel forging was thus ruined.

This chapter on the heat treatment of steel and other materials discusses in detail the precautions necessary to successful practice, and will undoubtedly prove very useful. It is followed by an equally comprehensive treatment of case-hardening problems, and by a collection of excellent notes on iron and steel castings. The remainder of the volume is devoted mainly to non-ferrous and non-metallic materials of construction.

The work is clearly printed and some 220 illustrations are included in the text, together with much valuable tabular matter.

BOOKS RECEIVED.

"*Hutte*," *Taschenbuch für Betriebsingenieure*. Berlin: Wilhelm Ernst and Son.

Aeronautical Research Committee. Reports and Memoranda. No. 880. *Flight Tests with R.A.E. Electrical Indicator*. By the Staff of the Royal Aircraft Establishment. [Price 1*s.* 3*d.* net.] No. 881. *The Efficiency of a Tandem System of Airscrews*. By H. Glauert. [Price 3*d.* net.] London: His Majesty's Stationery Office.

Power-House Efficiency Control. By John Bruce, A.M.I.E.E. London: Sir Isaac Pitman and Sons, Limited. [Price 12*s.* 6*d.* net.].

Fats: Natural and Synthetic. By W. W. Middleton, D.Sc., and T. Hedley Barry. London: Ernest Benn, Limited. [Price 25*s.* net.]

Der Wärmeüberganz an Strömendes Wasser in vertikalen Rohren. By Dr. Ing. Waldemar Stender. Berlin: Julius Springer. [Price 1·25 dols.]

Zur Berechnung des beiderseits eingemaerten Trager unter besonderer Berücksichtigung der Längskraft. By Fukuhei Takabeya. Berlin: Julius Springer. [Price 0·75 dols.]

Department of Overseas Trade. Report on the Economic and Financial Conditions in Brazil. September, 1923. By Ernest Hambloch. London: His Majesty's Stationery Office. [Price 3*s.* net.]

Album de Plans de Pose pour L'Installation de la Force par L'Électricité. By H. de Graffigny. Paris: Gauthier-Villars et Cie. [Price 7 francs.]

Marking Out for Machinists. By Capt. Richard Twelvetrees. London: Percival Marshall and Co. [Price 9*d.* net.]

Practical Hand Forging.—By Captain Richard Twelvetrees. London: Percival Marshall and Co. [Price 9*d.* net.]

Fitting and Adjusting Bearings. By Capt. Richard Twelvetrees. London: Percival Marshall and Co. [Price 9*d.* net.]

The Radio Society of Great Britain.—The Annual Conference of Affiliated Societies of the Radio Society of Great Britain will be held at 2 p.m. on Saturday, March 1, at the Institution of Electrical Engineers.

Kelvin Centenary.—Arrangements are being made by a committee convened by the Royal Society to celebrate the centenary of the birth of Lord Kelvin. Lord Kelvin was born on June 26, 1824. The chairman of the committee is Sir Richard Glazebrook, the members being prominent men belonging to British technical institutions. The hon. secretary is Mr. D. N. Dunlop. A large number of Dominion, American and foreign men of science and engineers will be attending conferences at the British Empire Exhibition, and July 10 and 11 have been selected as convenient dates for the celebrations. These will include a meeting at which Sir J. J. Thomson will deliver a memorial oration, and a dinner at which the Rt. Hon. Earl Balfour will preside. There will also be an exhibition of Kelvin apparatus.

INDUSTRIAL NOTES.

The meeting of representatives of the port labour employers and of the dockers, announced in our last issue, was held in London on Monday. At the close, Mr. F. C. Allen, on behalf of the employers, stated that they were willing to concede 1*s.* increase in the minimum daily wage, and 1*s.* addition per day of eight hours to piecework earnings, subject to several provisions to be entered into governing the latter addition. As regards maintenance and casual work, a sub-committee of the National Joint Council for Dock Labour would be set up to explore and report on the situation to the National Joint Council. This offer was rejected by the workers' representatives, who maintain their original demands in their entirety.

The employers' statement added that British shipping was in a deplorable situation, voyage after voyage of steamers showing serious losses, this applying to all trades; to increase working costs would only add to the burden. It refuted the allegations made by the dockers' representatives as to the earnings of shipping companies, and gave the percentage increase of the present dockers' wage over pre-war on an hourly basis, the figures being: London, Port of London Authority, docker, 114 per cent.; shipowners' docker, 90 per cent.; Liverpool, 127 per cent.; Glasgow, general cargo, 87 per cent., coasting, 150 per cent.; Bristol, 87 per cent. In reply to this, the dockers' representatives argue that the employers have quoted the best earnings they could find, there being other instances in which the men have to work long hours and overtime to reach the higher wage figures put forward.

Following the unsuccessful meeting of last Monday, the Minister of Labour, Mr. Tom Shaw, took the matter in hand and has since repeatedly met deputations of the two sides in conference.

The secretary of the London Iron and Steel Exchange, Limited, states that the position in the iron and steel market creates the impression that a considerable demand would develop if business activities were not held in check by outside factors, of which the principal are the threatened dock strike and the possibility of further labour trouble later on. Neither manufacturers nor merchants care to enter into forward commitments under the prevailing circumstances, and this is restricting the amount of work which is being given out. The railway strike has caused delay in deliveries in certain branches of the trade, and foreign buyers have taken advantage of this in some cases to cancel their orders. Most of the cancellations, however, have been by Japanese buyers, who placed orders for delivery before March in order to take advantage of the suspension of the customs duties on steel material required for constructional purposes. In some cases the railway strike has made delivery before the necessary date impossible. The Continental steel industry, however, is in a worse position than the British, as, owing to the congestion at the Antwerp docks, the transport of goods to that port is temporarily prohibited. The Continental trade is reported to be seriously disorganised, as the works are unable to despatch their new production and, as a result, large tonnages are accumulating and interfering with output. Under these conditions, the Continental manufacturers are maintaining prices and are only quoting for far forward delivery. In this country production is continuing at a satisfactory rate, and works, generally, have sufficient orders on their books to last for a few weeks. The light tonnage of new business coming forward, however, is beginning to cause anxiety.

A report is current to the effect that the Federation of Engineering and Shipbuilding Trades has lodged a national application for an advance in wages of 10*s.* per week, for shipyard workers, with the Shipbuilding Employers' Federation. The last cut in the balance, 10*s.*, of the 26*s.* 6*d.* war bonus granted to the skilled shipyard workers, was effected in December, 1922, when the war bonus was withdrawn in its entirety.

The Holyhead No. 2 branch of the National Union of Railwaymen, which counts amongst its members railway shopmen, firemen, seamen and stewards, decided unanimously at a meeting last Saturday to call upon the executive committee to request the railway companies to grant an increase of 10*s.* per week all round. The North-Eastern Shopmen's Vigilance Committee of the same Union passed at Darlington on the same day a unanimous decision requesting the executive committee to demand from the railway companies a 10*s.* advance per week for all railway shopmen members of the Union, and that the 16*s.* 6*d.* war bonus be added to the basic rates.

Mr. C. T. Cramp, secretary of the National Union of Railwaymen, has sent a circular to all the branches, in which he claims that the Union has amended and improved the agreement made between the railway companies and the Associated Society of Locomotive Engineers and Firemen. The additional terms arrived at between the Union and the companies are the following:—

"*Classification of Drivers*.—It is further agreed that for the computation of the 313 turns of main line duty all such turns worked by any man after he has become entitled to his 14*s.* rate shall be credited to him irrespective of whether such turns were worked either prior to or subsequent to the decision of the National Wages Board.

"*Sunday Duty*.—The companies agreed that the practice of calling trainmen on for short turns of duty and of booking men off at out stations after working short turns of duty would be kept to a minimum, and that instructions would be issued to this effect. They further agreed to forward to the N.U.R. typical examples of such workings from each of the four systems.

"Other matters were raised by the N.U.R., and the companies agreed to an immediate meeting between the N.U.R. and the railways staff conference in order to arrive at an agreement."

In the circular Mr. Cramp denounces the recent strike action by the Society, since, he adds, that these terms were arrived at without any weakening of the Union's funds, without breaking the Union's word, and without any disturbance of its machinery.

Mr. F. Bramley, secretary of the General Council of the Trades Union Congress, accompanied by Mr. E. L. Poulton, called last Friday on Mr. Tom Shaw, Minister of Labour, with a view to urge that immediate steps be taken by Government to give effect to the Washington Conference in the matter of the 48-hour working week.

According to the Chinese Government Bureau of Economic Information, the Peking-Hankow Railway, acting with the approval of the Ministry of Communications, has promulgated regulations governing rewards to workers. They may be granted as a bonus, as an increase of wages, or by promotion. A bonus is to be given to workers who save time or material in connection with any job, who carry out some urgent or difficult work, maintain double speed in work as measured by quantity of product, put down strikes and riots, drive trains for a year without accident, keep oil and coal consumption of locomotives within a prescribed limit per kilometre, or who render meritorious service in case of accident. A special bonus is to be granted for length of service. Faithful performance of duty for five consecutive years, or invention of machinery or instruments for use on railways is to be rewarded by an increase in wages. Unusual skill, special merit, and long service are to be rewarded by promotion.

In accordance with the agreed recommendation of the National Conference of the National Federated Electrical Association and Electrical Trades Union at Manchester on the 7th inst., all rates of all grades will be increased as from the first pay day following Sunday, March 2, for the period covered by that pay day. The revised rates under the National Wages Agreement for Electrical Contracting Industry, payable as from that date will be as follows: Grade A, 1*s.* 10*d.* This rate includes a travelling allowance. No further allowances to be paid except as provided by rule 9 of the London rules dated February, 1920. Grade B, 1*s.* 7$\frac{3}{4}$*d.* Grade C, 1*s.* 6$\frac{1}{4}$*d.* Grade D, 1*s.* 4$\frac{3}{4}$*d.* These rates will remain current up till and including December 31, 1924.

Judge E. H. Gary, chairman of the United States Steel Corporation, has informed President Coolidge that the shorter working day established in the iron and steel industry, in place of the 12-hour day, has increased the cost of production by 10 per cent., adding that efficiency may reduce this extra cost. According to a report in this connection, the Government is of opinion that demands for higher wages, when granted, generally correspond with a sacrifice on the part of consumers in the shape of higher cost of living.

Japanese Navy Estimates.—During the present quarter the Japanese naval estimates have been laid before the Diet. They amount, approximately, to £24,000,000. Three 700-ton mine-sweepers, about which no details are known, have recently been completed, together with submarine No. 59. The light cruiser Sendai was launched on November 30. The details of these vessels are as follows: Light cruiser Sendai—Displacement, 5,600 tons; horse-power, 90,000; speed, 33 knots; length, 500 ft.; beam, 47 ft.; draught, 16 ft. Armament, 7 5·5 in.; 2 12-pounder anti-aircraft guns; 4 double 21-in. torpedo tubes. Submarine No. 59—Displacement, 900 tons (surface), 1,080 tons (submerged); speed, 17 knots (surface), 10$\frac{1}{2}$ knots (submerged): length, 232 ft.; armament, 1 12-pounder and 4 21-in. torpedo tubes. Submarine No. 68, of a smaller class than No. 59, has also been completed. No details are at present available.

THE BURSTING OF THE RITOM LAKE TUNNEL.

WHEN the tunnel of the Ritom Lake hydroelectric power plant in Switzerland, to which we have referred on several occasions, had burst in July, 1920, a great number of very fine, mostly longitudinal cracks were discovered in the tunnel walls, and it was considered that these cracks were due to a yielding of the rock under the hydraulic pressure of 4·2 atmospheres. A committee of experts, engineers and geologists, was subsequently appointed to investigate the problem with special regard to several other subterranean hydraulic conduits then under construction. A report on these investigations has been published, in the *Schweizerische Bauzeitung* of January 5 and 19, by Mr. A. Schrafl, director-general of the Swiss Federal Railways.

In order to take measurements of any widening of the tunnel profile, Messrs. A. Amsler and Co., of Schaffhausen, constructed a special expansion recorder. The machine consists of a strong pillar which is vertically fixed in the tunnel section under test, the section being hermetically closed at both ends by strong gates. Half way up the pillar is mounted a steel disc; seven radial arms of steel stretch from the disc to the tunnel walls. Each arm of the spider is firmly attached with its outer end to the tunnel wall; the inner end rests loosely on the disc, which can be turned about its horizontal axis by means of a cord from outside the tunnel section. When the section is filled with water and the disc is turned, the style at the inner end of each arm describes a circle on the disc.

When in the experiments the water pressure in the section was increased, step by step, by increasing the height of the water column at the intake to the pressure pipes of the plant, the circle changed into a series of concentric arcs, showing that the water pressure actually expanded the tunnel profile. The experiments were made in tunnel sections, up to 0·5 km. in length, and in firm rock (biotite gneiss) as well as in rather soft shales (serezite shale). Calculated on a water head of 40 m. and a tunnel diameter of 3 m., the diametrical expansion amounted on an average to 0·05 mm. in the first case, and to 0·8 mm. in the second. The yielding of the rock was both elastic and plastic; the hard rock almost recovered when the pressure was removed; the soft rock showed a decided plastic set. Experiments with concrete-lined walls were also made. The effects observed were, of course, partly thermal, especially because the water was mostly colder than the relatively warm rock. But a real expansion of the tunnel by the hydraulic pressure seems to have been established for the first time. The Committee had made enquiries in Europe and America, and the experiments which are interesting, though probably not of great practical importance, seem to be quite novel.

THE ECONOMICAL THICKNESS OF INSULATION IN REFRIGERATOR CARS.*

By ARTHUR J. WOOD, STATE COLLEGE, PA., Member of the Society, and PHILIP X. RICE, DANVILLE, Ill.

THIS paper aims to explain a reasonably simple method for determining quickly and accurately the most economical thickness of insulation, and, further, to discuss some of the many factors which enter into the question of the economical design of insulated walls. Although this discussion is concerned with refrigerator cars, the possibilities of the method, modified to meet the individual requirements, appear to be unlimited.

2. In a paper by Mr. P. Nicholls presented at the joint meeting of the A.S.M.E. and A.S.R.E. in December, 1922, there was developed a formula for solving problems similar to the one in question. He pointed out that trial calculations are laborious and unsatisfactory and that a better plan would be to develop a general equation which included all the factors in determining the economical thickness of insulation. The authors pointed out some of the practical limitations in applying an equation containing many variables and proposed a simple method requiring the use of charts. Rectangular co-ordinates may be used to advantage where there are but few factors, but are not so well adapted for complex relations; in which case nomographic or alignment charts, as here shown, reduce the difficulties to a minimum.

3. If the trend in the present development is an indication, the refrigerator car of yesterday will not be the refrigerator car of to-morrow. The steam locomotive has passed through a similar transition; when wages, fuel costs and operating expenses were low, there was no great incentive to obtain the greatest economy and highest efficiency. In somewhat the same way when the prices of perishable food products were low and the supply abundant, the question of accurately accounting for the heat losses in refrigerator cars or of the spoilage of some of the products, was not a matter of very serious concern. Not so to-day. The higher cost and greater demand have resulted in the analysis of costs which heretofore were regarded as unimportant. Furthermore the better understanding of the laws of heat transmission and the determination of trustworthy constants have brought about more rational methods of design.* The study of the authors indicates that nearly all of the refrigerator cars in the United States are insufficiently insulated. Until recently, papers dealing with an analysis of the entire problem have not been published.

4. The saving of perishable food and the reduction of the amount of ice required for that purpose, must be balanced against the various factors to accomplish this saving. Among many items which the authors consider are: the percentage of time cars are in service, cost of transporting extra weight of insulation, depreciation of the cars, required amount of insulation for a particular structural design, effect of radiation, and the relative amount of absorption of heat due to different colours of paint. These and other factors must all be co-ordinated and the solution made simple and direct.

THE FACTORS.

5. The following factors enter into the determination of the economic thickness of insulation of a refrigerator car:

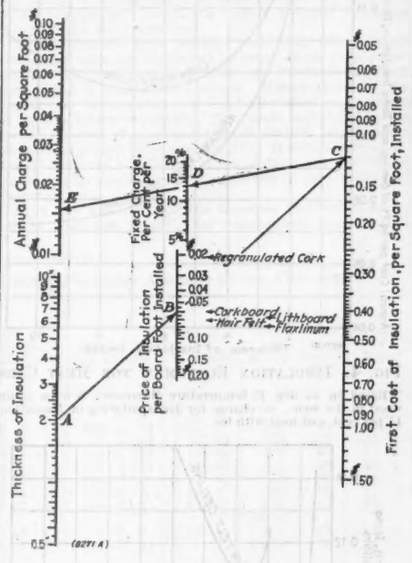


FIG. 1. INVESTMENT COST.

Investment.—Fixed charges due to ownership of insulation (Fig. 1).

(*a*) Thickness of insulation.
(*b*) Price per board foot of insulation.
(*c*) Fixed charge, per cent., including interest, taxes, maintenance and depreciation.

Cost of refrigeration or heating (Fig. 2).

(*d*) Conductivity and economic thickness of the material whose economical thickness is to be determined.
(*e*) Conductivity and thickness of other parts of structure, such as structural wood, etc.
(*f*) Resistance of air spaces and surface resistance.
(*g*) Difference between the temperatures of the air on the two sides.
(*h*) Percentage of year in which the refrigerant or heat is employed.
(*i*) Price of ice, refrigerant, or heat delivered to room to be insulated.

Transportation.—For railroad-owned refrigerator cars a transportation charge is to be included (Fig. 3).

(*j*) Thickness of insulation.
(*k*) Density of insulation.
(*l*) Miles per year.
(*m*) Cost of transporting extra weight of insulation.

These factors are discussed at the close of the paper. Their application to practical problems is brought out by a study of the accompanying charts.

GRAPHICAL CHARTS.

6. Fig. 1, which has to do with fixed charges on insulation, is one of the simplest forms of alignment charts and may be used for calculating the yearly investment as related to interest, taxes, maintenance, and depreciation. The positions of the names of insulating materials on the chart are to be used with due caution, for the prices as indicated by the positions of the arrows may vary considerably, depending in part on the amount purchased, the grade of insulation, and the market prices. For most materials it is safer to be guided by the actual quotations from manufacturers. Suppose the question is to find the annual charge per square foot for 2-in. corkboard selling at 6 cents per board foot and with a fixed charge of 13 per cent. per annum. Solution: Since the cost of insulation per board foot is 6 cents the "first cost" for 2-in. insulation will be $6 \times 2 = 12$ cents; which with a fixed charge of 13 per cent. a year will give $12 \times 0{\cdot}13 = 1{\cdot}56$ cents or 0·0156 dols. per square foot. This answer may be read at a glance by following the straight lines ABC and CDE of the alignment chart,* Fig. 1, starting with 2-in. thickness of insulation. The scales on these charts should cover the usual range of values for the class of problems encountered, and the results for any particular case may be read directly and variations of individual values noted. This is essentially a multiplication chart which covers a wide range of values for the factors involved.

7. Charts of similar character may be used for many classes of problems in which all but one of the variables are known or assumed. If several materials are to be compared, the same procedure, in general, can be used to get the annual costs for various thicknesses.

8. Fig. 2 is a chart constructed primarily for calculating the annual cost of ice, but may be used for the cost of refrigeration or heat. For important work the engineer should carefully determine the conductivities of the materials to be studied, using values given by trustworthy authorities for the density, moisture content, structural condition due to years of service, &c. Data on some of the more common dry materials for various compositions and of different densities were published in 1915 by the Bureau of Standards and have been reprinted in various books and articles since they were first published.† On Fig. 2 will be found the names of two materials adjacent to the values of conductivities which are believed to be approximately correct for these insulating materials when new. The prices will vary according to market conditions, grade of insulation purchased, &c.

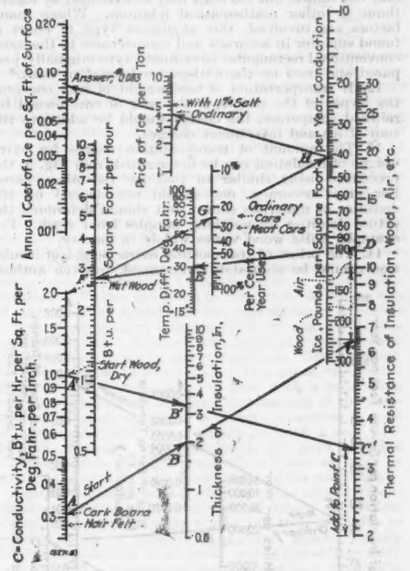

Annual Cost of Ice per Sq. Ft. of Surface
Price of Ice per Ton
Square Foot per Hour
Temp. Diff. Deg. Fahr.
Per Cent of Year Used
Thickness of Insulation, In.
Thermal Resistance of Insulation, Wood, Air, etc.
C = Conductivity, B.t.u. per Hr. per Sq. Ft. per Deg. Fahr. per Inch.
Answer, 0·0156
With 11% Salt
Ordinary
Ordinary Cars
Heat Cars
Wet Wood
Dry Wood
Air
Ice, Pounds per Square Foot per Year, Conduction
Start Wood, Dry
Start
Cork Board
Hair Felt
Add to Point C

FIG. 2. ANNUAL COST OF ICE OR REFRIGERATION.

Average values for surfaces as used in above chart: One surface, resistance, 0·8; two surfaces, still-air resistance, 1·6; one surface, air moving at 50 ft. per min., 0·5; one surface, air moving at 1,000 ft. per minute, 0·3. For air spaces, use reciprocal of heat-transmission values as obtained from Bureau of Standards tables. (*See* Kent's M.E. Handbook, 10th edition, p. 629.)

9. A sample floor calculation will illustrate how the graph is to be used. Starting at A, Fig. 2, with corkboard, conductivity = 0·308, lay a straight edge through the same trial thickness as in Fig. 1, namely, 2 in., and read on the right-hand scale a thermal resistance of 6·5. To this add the inside surface resistance of 0·8 and outside surface resistance of 0·5 (assuming a velocity of 500 ft. per minute as an average of standing and running while iced). Also, add the thermal resistance of structural wood obtained by assuming an average value C = 1 and projecting a straight edge through 3½ in. (the thickness of the structural wood), which gives a resistance of 3·37. The total floor resistance is $6{\cdot}5 + 0{\cdot}8 + 0{\cdot}5 + 3{\cdot}37 = 11{\cdot}17$ at point D. Now, starting from a resistance of 11·17, lay a straight edge through "Temperature Diff. Deg. Fahr.," say, 30 deg., and get 2·7 B.Th.U. per square foot per hour. Again, reversing the direction from 2·7 B.Th.U., go through "Per Cent of Year Used," taken here as 25 per cent., and get 41 lb. of ice melted per square foot per year due to conduction through the floor. Reversing, go from 41 lb. through "Price of Ice" (or refrigerant or heat), say, 4 dols. per ton of ice

* Paper read at the New York meeting of the American Society of Mechanical Engineers, December, 1923.

* An illustration in point is the design of the new refrigerator cars for the C.M. & St. P. Railway, described in *Railway Review*, June 16, 1923.

* For description of method of preparing alignment charts of this description see chap. iii, Graphical and Mechanical Computations, by Joseph Lipka. The principles underlying the construction of nomographic or alignment charts have been fully developed by M. d'Ocagne of Paris in his Traité de Nomographie.

† Kent's M.E. Handbook, Tenth Edition, page 630.

delivered to bunkers of car, gives 0·083 dols. as the annual cost of ice per square foot of floor. For other thicknesses it is necessary to use the chart again; the answers are not directly proportional to thicknesses, because the sum of the wood and the surface resistance does not vary with change in thickness of the cork or felt.

10. The scales of Fig. 2 were chosen particularly for refrigerator-car insulation. This same chart, when used within the limitations of the scales, may be used in solving problems where the refrigeration is supplied to the cold-storage room by a circulating medium. In this case the upper right-hand scale may be changed from pounds of ice into B.Th.U. by multiplying the figures on the chart by 144 and marking the divisions as B.Th.U. The middle upper scale of Fig. 2 may be made to represent the cost of heat per B.Th.U. transferred from the refrigerating room, but the conversion of this scale from the basis on which it is now given on the chart to one showing cost per B.Th.U., becomes a problem involving many factors under two items, (*a*) capital costs, (*b*) production costs, and is outside the range of the present discussion.

11. For certain problems the range of these graphs may not suffice, but the scale may be extended by logarithmic or other mathematical relations. Where many factors are involved, this alignment type of chart is found superior in accuracy and compactness to the more conventional rectangular co-ordinate type originally prepared and used by the authors for insulation work.*

12. If transportation of tare weight of cars concerns the owner of the car, as is the case of cars owned by railroad companies, the charge should be added to the sum of ice and investment charges.

13. The amount of transportation charge for extra weight of insulation can be determined from Fig. 3, the procedure being similar to that for the other charts. For great accuracy, one should not depend on the densities of materials shown, but should determine the actual densities by weighing samples from stock. For example, balsa wood varies widely in density.

14. The prices of transporting extra weight of insulation cannot be accurately determined, but the authors

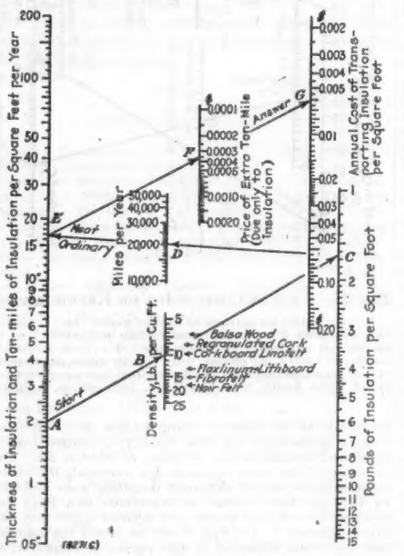


FIG. 3. ANNUAL COST OF TRANSPORTING INSULATION.

would submit 0·0007 dols. per ton-mile of extra weight on level routes, 0·0024 dols. for mountain roads, and 0·0010 dols. for transcontinental service as being the best approximations available as brought out by them in a discussion of the cost of transporting extra weight of cars, which will form a chapter of a bulletin to be issued later. For purposes of illustration, the value of 0·00035 dols. has been assumed (point F). The final answer is at G and gives 0·6 cent per square foot as the annual cost of transporting the insulation in the above example.

ECONOMIC CURVES AND RESULTS.

15. One of many applications of the foregoing may be indicated. Having thus calculated all the charges for various thicknesses of various insulating material, economic curves similar to Fig. 4 can be plotted for floors under prescribed conditions of operation. Other curves can be drawn for ceilings with their own peculiar conditions. Fig. 5 shows three economic curves for ceilings and floors of refrigerator cars engaged in general perishable-fruit business, the data for plotting the curves being taken from Tables I, II and III. The conditions under which standard fruit cars operate in average trans-continental trips from April to September is shown in the notes under the tables.

* Referred to by the authors in their discussion of paper on "Economic Thickness of Insulation," by P. Nicholls, December, 1922 meeting A.S.M.E. and A.S.R.E. See *Refrigerating Engineer*, Feb., 1923.

16. A comparison of the curves in Fig. 4 reveals the economic superiority of regranulated cork for floors. The curves show that the minimum annual cost per square foot of cork board is 0·114 dols., whereas with regranulated cork the minimum is 0·072 dols. The respective economic thicknesses are seen to be 6·5 in. and 10·5 in. If the structural wood was considered to be wet, and this is the safe assumption, the relative advantage of regranulated cork as compared with cork-board would be even greater. If steel floors were used instead of wood, regranulated cork would also show a greater economic advantage.

17. Fig. 5 shows that even for the same material the economic thickness may be much more for floors than for ceilings. Probably the economic thickness for side insulation would be different from roofs or floors because the average temperature difference in the side is different from other parts of the car and the structural wood and number of air spaces may be different. The curve for hair felt appears to be a minimum at 1 in., but in practice such a thin ceiling should not be used in the car because

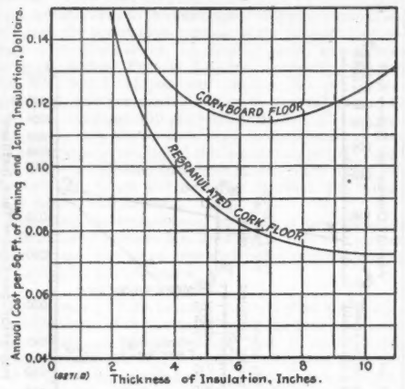

Annual Cost per Sq. Ft. of Owning and Icing Insulation, Dollars.
CORKBOARD FLOOR
REGRANULATED CORK FLOOR
Thickness of Insulation, Inches.

FIG. 4. INSULATION ECONOMICS FOR MEAT CARS.

Based on 35 deg. F. temperature difference; 3·3 in. of dry wood in the floor; no charge for transportation of insulation; 11 per cent. salt used with ice.

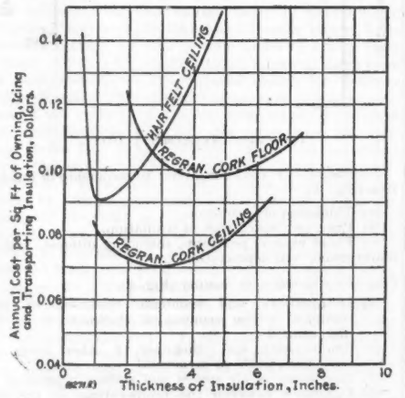

Annual Cost per Sq. Ft. of Owning, Icing and Transporting Insulation, Dollars.
HAIR FELT CEILING
REGRAN. CORK FLOOR
REGRAN. CORK CEILING
Thickness of Insulation, Inches.

FIG. 5. INSULATION ECONOMICS FOR TRANSCONTINENTAL FRUIT CARS.

(*See* Tables 1, 2, and 3 for details.)

of the greater tendency for the top layers of fruit to spoil. The economical thickness of ceiling insulation for overhead refrigerating systems, such as the A, B, C, Moore, or the side-draft bunker system* would be considerably greater than the thicknesses shown in Fig. 5, because of the superior refrigeration in the upper part of the car.

18. A comparison between the curves of Figs. 4 and 5 indicates a great difference in economic thickness. This is due to the colder inside temperatures of the meat car and to the fact that meat packers do not have to pay for transportation of extra weight of insulation. With the present system of car interchange, the cost of transporting the extra weight of a thoroughly insulated car is not assessed against the car owner, even if the owner is a railroad company. If only one road should adopt thicker insulation, the other railroads, over whose lines the car operates, would unwittingly bear the extra cost of transporting extra insulation. Naturally, this loss would come out of what would perhaps otherwise be profit for the roads handling the car. Therefore, as interchange customs now stand, the economical thickness insulation should be calculated with practically no transportation charge. To be exact, of the car's annual mileage of, say, 20,000, the owner of the car may haul it only 3,000 or 5,000 miles, and the transportation factor should be reduced accordingly. Small road owning refrigerator cars would, therefore, insulate them more thoroughly than would long roads. In fact, the short road might well neglect the transportation cost of thick insulation and use insulation much thicker than is now commonly employed. Furthermore, real thick insulation would reduce spoilage claims somewhat, and obviate much criticism from shippers.

* See *Railway Mechanical Engineer*, June, 1923, or *Refrigerating Engineering*, June, 1923, Tests on a Refrigerator-Car Model, by P. X. Rice.

TABLE I.—*Economics of Trans-Continental Fruit Cars—Hair-Felt Ceilings.**

	Thickness in Inches.					
	1.	2.	3.	4.	5.	6.
Interest ..	0·009	0·018	0·027	0·036	0·045	0·054
Ice	0·067	0·047	0·038	0·031	0·026	0·023
Transportation	0·015	0·031	0·045	0·063	0·079	0·095
Total ..	0·091	0·096	0·110	0·130	0·150	0·172

* Based on service from April to September, inclusive. Average shade temperature, 64 deg. F.; fair-weather factor, 70 per cent.; average increment on roof, 8·2 deg. × 70 per cent. = 6 deg.; average total roof temperature, 64 + 6 = 70 deg. average ceiling temperature (2 in. below), 50 deg.; structure wood in ceiling (2·5 in.), dry; air spaces in ceiling, 2 in.

TABLE II.—*Economics of Trans-Continental Fruit Cars—Regranulated-Cork Ceilings.*

(Footnote to Table I applies also to this table.)

	Thickness in Inches.					
	1.	2.	3.	4.	5.	6.
Interest ..	0·003	0·006	0·009	0·011	0·014	0·017
Ice	0·070	0·051	0·040	0·033	0·029	0·025
Transportation	0·008	0·015	0·022	0·029	0·036	0·044
Total ..	0·081	0·072	0·071	0·073	0·079	0·086

TABLE III.—*Economics of Trans-Continental Fruit Cars—Regranulated-Cork Floors.*†

	Thickness in Inches.					
	2.	3.	4.	5.	6.	7.
Interest ..	0·006	0·009	0·011	0·014	0·017	0·020
Ice	0·100	0·071	0·060	0·047	0·042	0·037
Transportation	0·015	0·022	0·029	0·036	0·044	0·051
Total ..	0·121	0·102	0·100	0·097	0·103	0·108

† Based on service from April to September, inclusive. Average shade temperature, 64 deg. F.; average increment under floor, 3 deg.; average total floor temperature, 67 deg.; average temperature 2 in. above floor, 37 deg.; temperature difference, 30 deg.; structural wood (3¼ in.), dry.

AIR-SPACE CONSTRUCTION.

19. Cellular paper insulation has possibilities in connection with the economics of refrigerator cars, principally because of its light weight. The natural criticism to such a suggestion is that paper insulation would disintegrate in the presence of the inevitable moisture that accompanies refrigeration. The authors do not know of any tests on such material, except those made at State College on a piece of paper insulation 1 ft. sq. and 1 in. thick, with one edge nailed to an improvised flagmast. This insulation has withstood the rain, snow, sun, and gales for one year, and apparently would still function as refrigerator-car insulation. It was constructed of hard glazed wrapping paper, coated on both sides with shellac to fasten together the corrugated sheets and to waterproof the paper. Half-inch corrugations were put between flat sheets of paper, and two of such series constituted the 1-in. thickness. The authors also constructed paper insulation 3 ft. sq. and 2 in. thick, in a similar arrangement. This weighs only one-eighth as much as hair felt of equal thickness or one-quarter as much as hair felt of equivalent thermal resistance.

20. Objection has been made to air-space construction on account of the uncertainty of the air spaces remaining securely sealed. Apparently, no dependable quantitative data on air leakage in air spaces are available, but information from a number of engineers who have examined the conditions after cars have been in service, leads the authors to believe that in most cases air spaces are maintained for a long time without any serious change. The "heat meters" which are being developed independently by the Engineering Experiment Station and by the Research Laboratory of the American Society of Heating and Ventilating Engineers, may be used to measure directly the effectiveness of old and new cars of various constructions. Until satisfactory tests are made to settle the difference of opinion on the question of air leakage, the authors will continue to believe that there are undeveloped possibilities in air-space construction.

(To be continued.)

TINPLATE MANUFACTURE IN JAPAN.—We read in *The Iron Trade Review*, Cleveland, Ohio, that the attempt of the Government steel works to establish a domestic tinplate industry is proving successful. Another lot of 150 tons has been marketed at ruling prices. The works are installing at Yawata three more furnaces purchased in England. They will add 300 tons to the plant's monthly production of tinplates and 250 tons to the black sheets.

REPAIR AND UPKEEP OF PNEUMATIC TOOLS.*

By R. W. WILSON, of Newcastle-on-Tyne.

THE scope of this paper is to consider what is necessary to maintain in efficient operation and in economical service the pneumatic tools commonly used in engineering workshops and shipbuilding yards. These tools may be roughly divided into two classes, namely, reciprocating tools or pneumatic hammers, and rotating tools or pneumatic drills. Pneumatic tools are used in rough surroundings, and are operated by men who would also, perhaps unthinkingly, be characterised as rough. They must, therefore, be rough and strong externally so that they can withstand the most strenuous use and unlimited abuse, yet in the details there are scarcely any machines so carefully made and so precisely sized in all responsible dimensions. The readiness of compressed air to leak away wherever it finds a chance is notorious, and yet the cylinder-heads, the valves and other parts requiring air-tight joints are so perfectly surfaced and fitted that they go together and are always used metal to metal absolutely without packing.

Every part of a standard pneumatic tool is so accurately made to gauges that stocks of parts are maintained, and these pieces can always be relied on to interchange with and replace each other. The manufacture of these tools requires the coincident compliance of many exacting conditions; the trying out of successful details of the design, the relative areas of ports and passages, the sizes of the several parts for this material co-operation, the selection of the most suitable and enduring materials for each part and their proper heat treatment and manipulation to secure strength and slow-wearing qualities. This means carefully selected, trained and long experienced workmen; installation of automatic and often special machinery, costly collections of gauges, jigs and original tools for special operation; the testing and the rigid inspection of the product before it is sent out.

The efficient operation of these machines should be facilitated by ensuring a good supply of air, free from moisture, convenient hose connections, means for keeping the pipe-line free from ice, and provision for oiling the machines as required. Efficient and economical service demands that riveting hammers shall have sufficient speed and power to drive the rivet while it is still hot; that they do not vibrate or kick, to an extent that makes it difficult to guide, and that they shall respond to the throttle promptly giving light or heavy blows as desired under the full control of the operator.

The pneumatic tool room and stores should be supplied with spare parts and be able to supply promptly such accessories as experience has shown are necessary. The most trifling faults are liable to throw these tools into disorder, which either reduces their power, or cause them to kick and stick or start badly. The repair man should be competent to remedy such defects with a minimum of delay. Only a small percentage of repair men ever learn exactly why or how these tools operate, but if they remember that they worked properly when they left the factory, and learn to keep them in their original condition, it is all that is necessary. As tools come in for cleaning, the repairer should check their air consumption by comparison with a standard tool, examine carefully the surfaces which are supposed to fit together with an air-tight joint, remove any burrs with a very fine flat file, take away the sharp corners and countersink the pin-holes slightly.

The repair man should try, on a heavy block of wood arranged for this purpose, one of the hammers which is known to have sufficient power and works smoothly. With the working characteristics of this hammer as a standard, he will soon learn how fast a tool ought to run, how much vibration is to be expected under normal conditions and how rapidly the sett ought to cut into the wood when the tool is developing normal power. With these standards in mind he can test doubtful tools, and judge by comparison whether they be right or wrong. A good repair man will soon be able to state positively whether they be right or wrong, and readily diagnose faults.

The lubrication of pneumatic tools must be done judiciously. For pneumatic hammers, on no account must heavy oils be used; these tend to gum up the valves and may prevent the tools from working. A light machine-oil is the best to use. The way to oil the tool is to pour a little light machine-oil into the air-supply passages or opening before connecting on to the hose. When the tool is started the air will carry this oil into all working parts, and while the tool continues at work no further lubrication is necessary. It is desirable that every pneumatic hammer in use should be immersed occasionally in a box of mineral oil for a thorough cleansing, and if a tool has been lying in store for a period it should be also immersed in the oil bath previous to use and then lubricated as already described.

Important economies can be effected by paying careful attention to such matters as the sorting, cleaning, testing, maintenance of pneumatic efficiency, the carrying out of minor repairs, and lastly, the system adopted of issuing the tools to the operators.

It has already been pointed out that, taking it all round, no tools are subjected to more abuse than pneumatic tools, and anything that can be done to check that abuse is money twice saved. Money saved by the prevention of breakdown is far better than any system of repairs, however perfect. That tools, subjected to the severe stresses of pneumatic tools, should break down occasionally is not to be wondered at; it would be remarkable if they did not, but it is astonishing how the life of a tool can be prolonged by the exercise of care in use and keeping.

It is not sufficient for the foreman or chargeman to rate a workman soundly for carelessness when a tool is broken or lost. The only way is to make a workman responsible for the tools he is using by touching his pocket, and any economical system of tool issue must take this basic fact into consideration, even up to the extent of making an operator pay the full value of the tool broken or lost. Admittedly any system of the kind that penalises an operator is very difficult to introduce, but it can be done by the exercise of tact, and in the yard the author has in mind such a system was introduced and accepted by the men in the difficult labour period immediately following the war. In this yard every user of pneumatic tools is given a book when he starts work. On the book is printed the name of every pneumatic tool he is likely to use, a corresponding card, indexed under the Workman's Bd. No., is retained in the pneumatic tool store. The workman starts his career by obtaining from his foreman a requisition for the tools he first needs. These are entered in his book and on the tool store record; thereafter by producing the book he can exchange at the pneumatic tool store one tool for any other he may be in need of without reference to his foreman. All pneumatic tools are numbered, also pneumatic hose lengths ready fitted with connections. In addition to his book, a workman is also provided with a number of checks, one which he gives in to the pneumatic tool store whenever he gets a tool out. At the end of every week a workman must clear his machines and receive from the store foreman a chit to this effect before he can receive his pay. If for any reason a tool is not returned, or a tool is returned broken, the pneumatic store foreman gives to the workman a red slip with the value of the tool or damage entered thereon as a deduction from his pay. This rule is very strictly observed, making it impossible for a workman to receive his full pay until he can hand in a clearance note from the pneumatic store foreman. Deductions made from the workman's pay are of course refunded if afterwards the tool or part that is missing is found and returned to store. The justice of this is appreciated by the workmen and gives them confidence in the system.

Before being put away, all tools are carefully tested to ascertain that they are in good working order, especial watchfulness being exercised in checking air consumption, any tools observed to be consuming more air than the standard are immediately put in to the repairer's hands to be turned up and have worn parts replaced. Accurate costs of repairs are booked against each individual tool, and these are classified under the different makes of tools, in use—the result being a very complete record showing the repair cost of the tools obtained from different manufacturers. The table on this page gives such a record over a period of twelve months. The different makes of tools in use are indicated by letters, and the table is interesting as showing the great difference in the cost of upkeep of tools from various makers.

Accurate records must be kept of the power costs of running the compressors, which usually are easily obtained from the electric meter readings, and the maintenance cost of the plant. In a large shipyard on the north-east coast the actual cost of compressing 100,000 cub. ft. of free air to 100 lb. per square inch pressure with electric current at 1*d.* unit worked out as follows:—

Power	20*s.* 1*d.*
Circulating water	3*d.*
Labour	6*s.* ½*d.*

In a well-maintained plant there must be no leakages. Leakages are most usually found in the flexible hose-lines and connections. If left to themselves workmen will suffer leaks which cause them no inconvenience rather than stop their work for the purpose of obtaining a new hose-line. Where a number of tools are in use it is an economy to employ a man whose duty it is to go round inspecting the pipe-lines, re-wiring on leaky connections, and on occasion purposely to cut a leaky hose-line to compel a workman to go to the store for a new length of hose.

Another fault which is often met with is loss of pressure at the point where the tool is used. Nothing is so fatal to the efficiency of pneumatic tools as a drop in the air-pressure. Pipe-lines are sometimes overloaded and too many tools are supplied from a main much too small in diameter. Tables are given in text books as to the size of main to employ, and it is but poor economy to permit a drop in pressure of perhaps 20 lb. or even 30 lb. due to small mains. Another fault frequently met with is the throttling of air in the connections. Some connections are very bad in this respect. It is not an uncommon thing to fasten two lengths of hose with a connection having a hole perhaps less than half the area of the hose-pipes connected, or maybe a cheap connection is used for connecting with the service pipe with a cast hole through it rough and half-closed. It pays to have machined holes through connections made as large as possible compatible with the strength of the couplings.

Another source of trouble which requires careful watching are strainers. They are very necessary sometimes, especially in dirty or dusty places, but they are liable to get choked up at times very quickly. Makers usually fit strainer adaptors to all tools, and it not infrequently happens that a mysterious loss of power in a pneumatic tool may be traced simply to the gauze in the strainers getting choked up with dirt. These strainers are very easily cleaned by blowing air through the opposite way.

Water in the pipe-line is a frequent source of trouble. This is generally due to the after-coolers and air-receivers being too small, the hot air from the compressors not being properly cooled before entering the main. A good remedy for this is to introduce water traps in suitable places in the pipe system, and at these traps the water can occasionally be blown out. Moisture tends to choke the tools, and not infrequently causes ice to form in the valves and at the exhaust, also, it always tends to rust the internal parts of the tools, and thus may cause much damage. Water in the pipe-line collects at low bend and angles, and besides stopping the free flow of the air, in cold weather is very liable to freeze.

In order to ascertain the real worth of a pneumatic tool, it is obvious that some ready means of comparing one tool with another is essential. Opinions of workmen as to the merits of any particular make of hammer are largely influenced by prejudice, and the hammers they are accustomed to operate. In comparing hammers the following are points to which consideration must be given:—

(1) The actual time in doing a definite amount of work, say, closing a rivet; but to compare hammers in this way a knowledge of the weight and frequency of the blow is essential.

(2) Freedom from vibration, which enables the operator to use the tool for longer periods without undue fatigue.

(3) The weight, in order to avoid tiring the workman, by having to hold up a heavy tool.

(4) Flexibility and ease of control, so that light and heavy blows may be struck at the will of the operator.

With pneumatic drills comparisons are usually made by simple timing when drilling a definite diameter and depth of hole through a mild steel plate.

The machine shown in Fig. 1 (page 220) was designed by the author as a ready means of comparing the weight and frequency of the blows of pneumatic hammers, and as a result of many hundred of tests done on the machine, interesting results have been obtained. The weight of the blow is ascertained by gauging the crushing effect on prepared test-pieces in given periods of time, and the frequency of the blow by comparing the wavy line produced on a moving strip of paper by the action of the hammer, with a similar wavy line produced on the same piece of paper by a tuning fork of known vibrations.

The test-pieces, Fig. 2, which are made of mild-steel, usually ¾-in. diameter by ½ in. long, are placed in the cylinder marked A, Fig. 1. The strokes of the hammer are recorded on the strip of paper by the movement of

TABLE.—PNEUMATIC DETAILS.

Average Maintenance Cost for Drillers, Caulkers, Riveters, Pneumatic Machines for the Year 1922.

Effective Nos. of M/cs.	Description.	Age of Machine.	No. repaired.	Cost of Time, 12 Months.	Cost of Material, 12 Months.	Total Cost, 12 Months.	Cost of 1 for 12 Months.	Revs. per Minute.	Air Free consumption.	Weight of M/cs.
	Drillers.			£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*			lb. oz.
79	No. 2 N.R. A	1911–1920	246	108 16 3½	550 8 6½	659 4 9¾	2 13 7	339	35	35 0
17	No. 2 Rev. A ..	1911–1920	48	9 18 7½	65 5 1½	75 3 8¾	1 11 3¾	420	50	35 0
54	No. 4 A	1911–1919	283	78 6 0	428 6 11¾	506 12 11¾	1 15 0½	582	36	27 0
15	No. 2 B	1920	55	20 7 8¾	132 19 2¼	153 6 10¾	2 15 0½	388	40	40 0
26	No. 3 B	1920	102	39 0 2¾	102 17 5¼	141 17 8	1 7 9¾	556	30	23 8
46	No. 5 B	1920	129	30 10 7¾	93 8 7¼	123 19 3	0 11 4	609	28	14 4
29	No. 9 B	1920	95	32 8 6	123 17 10	156 6 4	1 12 10¼	136	42	38 0
	Riveters.							*Blows.*		
4	No. 9 C	1910–1911	9	1 14 1	3 14 8	5 8 9	0 12 1	750	25	26 0
90	No. 5 Combination JB D	1915–1920	321	95 4 4½	245 8 7¾	340 13 0	1 1 2½	1,000	37	34 0
22	Holder-on E ..	1912	7	0 12 3½	2 3 0	2 15 3½	0 7 10¾	—	—	25 0
32	Baby JB F ..	1912	40	9 3 0	11 3 3½	20 6 3½	0 10 1½	800	48	40 0
24	No. 4 H	1912–1919	4	0 5 6	0 4 0	0 9 6	0 2 4½	1,000	25	15 0
44	No. 5 H	1912–1919	171	31 12 3¾	75 15 4½	107 7 8¼	0 12 5	1,000	24	21 0
17	No. 6 H	1919	65	10 19 3	64 19 3½	75 18 6½	1 3 2½	760	26	23 4
12	No. 8 H	1919–1920	53	8 2 5½	43 13 5½	51 15 10¾	0 17 10½	700	30	24 8
33	No. 4 G	1914–1919	162	38 14 9	228 16 10½	267 11 7¾	1 13 0½	900	24	17 8
68	No. 6 W	1920–1921	253	77 13 1¾	65 0 5½	142 13 7¼	0 11 3½	1,500	26	17 8
4	No. 5 W	1920	7	0 19 1½	0 5 0	1 4 1½	0 3 5½	1,760	18	13 4
	Caulkers.									
14	K	1916–1920	33	24 7 9½	46 1 2	70 8 11½	2 2 8½	2,800	20	16 8
79	No. 2 M	1913–1919	262	42 4 10½	157 11 10½	199 16 8¾	0 12 11	2,800	20	16 8
		Totals ..	2,345	661 0 10	2,442 0 9½	3,103 1 7½				

* Paper read before The Institution of Mechanical Engineers on Friday, February 8, 1924.

the pencilled lever L, and on the same strip of paper are likewise recorded the oscillations of the tuning fork F, the strip of paper being made to travel by the clockwork mechanism M. Strips of paper are shown with the two wavy lines, one made by the hammer blows, and the other by the tuning fork vibrations, Fig. 5. Test-pieces, Figs. 3 and 4, are also shown to illustrate the crushing effect of the hammer blows. It is interesting to note that the edges of many of the crushed test-pieces are quite different in shape some assume a barrel or convex profile, Fig. 3, while others are pin-cushion or concave shape, Fig. 4. It was found by experiment that either shape of crushed test-piece could be produced by changing either the weight of the hammer used, or varying the diameter of the test-piece. The results showed that the convex shape of the test-piece was produced when a heavy hammer was used, and the concave shape was produced when a lighter hammer was employed. Further, this difference in shape was sometimes produced with hammers of the same rated capacity operating on similar test-pieces, although the measured distortion on the test-piece might be approximately the same in the two cases: the hammers with the slow beat usually gave the convex form, while the hammer with the quicker beat and lighter blow gave the concave form of crushed test-piece. It is clear that the convex-form of test-piece reproduced the conditions when a rivet is set up in the hole, such as is usually required when cup riveting on structional work is done, and that the concave form of test-piece reproduced the conditions required for flush riveting work where it is important to spread the rivet head quickly, such as shell riveting on a ship. This indicates how important it is that the weight of blow or size of any hammer should be suited to the class of work it has to do.

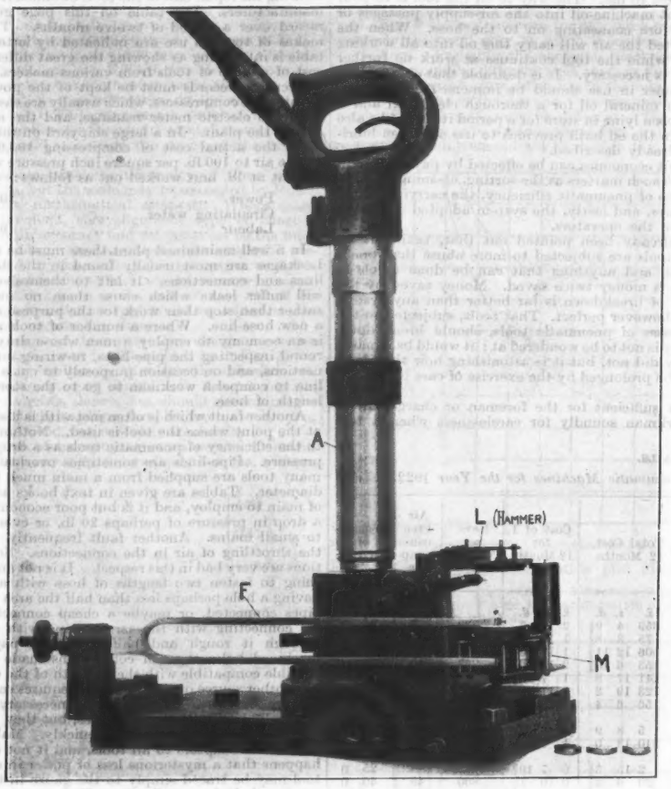


FIG. 1.

Very large numbers of tests have been made on this machine, and the diagrams (Figs. 6 and 7) will be of interest as showing a comparison between different makes of hammers. The hammers selected for comparison are all new tools. One is an American hammer, the second a French hammer, and the third an English hammer. Makers' names are purposely omitted, but the English hammer is of the author's own design.

Fig. 2 illustrates a test-piece ready for use. These test-pieces are prepared from mild-steel Brinell Test No. 114 to 118. They are accurately ground to size within a limit of 0·0005 in. on both dimensions.

Figs. 2 and 4 show the same test-piece before and after being crushed, and attention is directed to the difference in the profile. The test-piece, Fig. 3, has been crushed with a heavy riveting hammer, while the test-piece, Fig. 4 has been crushed by a light riveting hammer.

Fig. 5 is copied from a piece of the paper strip from the roll; both lines are traced simultaneously. The upper line is traced by the blow of the hammer, while the lower line is traced by the vibrations of the tuning fork. The vibrations of the tuning fork being known to be fifty per second, ten vibrations between the two vertical lines represent one-fifth of a second in time, and from this the number of beats or blows of the hammer per minute is easily calculated.

Series of tests were carried out with a view to ascertaining the amount of distortion on test-pieces of different diameters in equal periods of time. These test-pieces may be likened to rivets of different diameters, and it is interesting to compare the upsetting effect of different hammers; the measured distortion taken in conjunction with the final shape profile truly indicates the most suitable hammer to use on any particular size or class of rivet. These results are plotted in Fig. 6.

MILD STEEL TEST-PIECES. BRINELL Nos 114 TO 118.

Fig. 2. BEFORE CRUSHING.

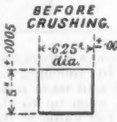
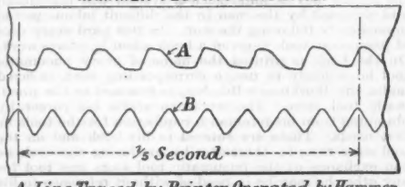


Fig. 3. AFTER CRUSHING. WITH HEAVY HAMMER, SHOWING BARREL-SHAPED OR CONVEX PROFILE.

Fig. 4. WITH LIGHT HAMMER, SHOWING CONCAVE PROFILE.

Fig. 5. SECTION OF TAPE USED ON HAMMER TESTING MACHINE.



A-Line Traced by Pointer Operated by Hammer.
B " " Tuning Fork (50 Vibrations per Sec.).
(8276.B.)

Further series of tests were made with a view to ascertaining the cumulative effect on a test-piece when subjected to repeated hammerings. A standard test-piece 0·625 in. by 0·5 in. long, was selected, and after every ten seconds of hammering was taken out of the machine, gauged to measure the distortion and put back again. The results are plotted in Fig. 7. The same three riveting-hammers were again employed as in the above test, and the tests were made at both 100 lb. and 80 lb. air pressure. The distortion is rapid at first, but after 20 seconds reduces until, between 50 and 60 seconds, very little further distortion takes place. An obvious lesson demonstrated by this diagram is the importance of having rivets the right length. If rivets are left a little too long, it is clear that it must be impossible properly to close them. Another rather remarkable result shown by this diagram is the very great loss in efficiency when the air pressure is dropped from 100 lb. to 80 lb. It clearly shows that the same amount of distortion can be produced on the test-piece in about half the time with air at 100 lb. than with air at 80 lb. and, as only about 10 per cent. more power is required to produce compressed air at 100 lb. over compressed air at 80 lb. this indicates how very important it is to use the maximum air pressure at which the tools are designed to work to attain the best results. Further, when it is considered that most pneumatic riveting is hot riveting and the rivet all the time is rapidly cooling, the importance of maintaining high air-pressure at the point where the tool is to be used cannot be over emphasized. This is indeed the crux of obtaining quick and sound work, and when these conditions prevail there is no fear but that pneumatic riveting will beat hand riveting not only as regards time but as regards the quality of the work produced.

Fig. 6. CHART SHOWING WORK DONE ON TEST-PIECES OF VARYING DIAMETERS IN 20 SECONDS BY THREE DIFFERENT RIVETING-HAMMERS OF SIMILAR RATED CAPACITY.

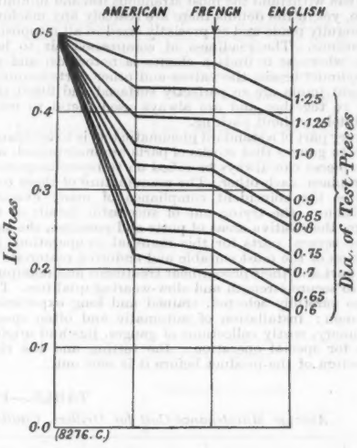
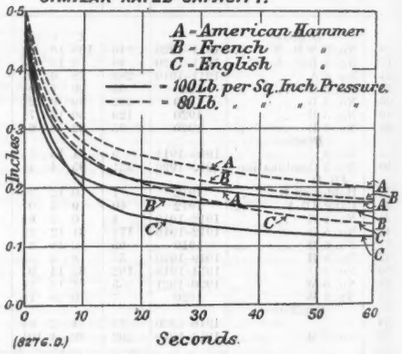


Fig. 7. CHART INDICATING WORK DONE ON A KNOWN TEST-PIECE IN EQUAL PERIODS OF TIME BY THREE DIFFERENT RIVETING-HAMMERS OF SIMILAR RATED CAPACITY.



THE EFFECT OF TEMPERATURE ON THE QUALITIES OF METALS.—At the meeting of the Royal Society held on Thursday, January 31, a paper was read by Mr. As Mallock, F.R.S., entitled "Summary of the Result. Obtained from Experiments made during the years 1918 to 1923 of the Effects of Temperature on the Properties of Metals." In this paper some results are given relating to the properties of iron and steel in the neighbourhood of the critical temperature, at which there is an abrupt alteration in specific heat, which, as the metal passes to the high-temperature state, is reduced to about one-third of its previous value. The coefficients of rigidity and thermal expansion undergo no discontinuous change. The rigidity increases slowly as the temperature rises to a low red heat, but at higher temperatures the change is rapid. At a bright red heat the metal still retains elastic properties, but with greatly increased viscosity, and thus oscillations which depend on rigidity are quickly damped out. The presence of small quantities of Si, S. P, and Mn, in the samples used in the experiments, prevent any absolute conclusion being formed as to the effect produced by carbon alone, but it is clear that carbon lowers the critical temperature, and prolongs the time occupied in changing from the high to the low temperature state while the metal is cooling.

SOME CHEMICAL ASPECTS OF WELDING.*

By Mr. J. R. BOOER, B.Sc., F.C.S.

General Physical Phenomena.—It has frequently been stated that welding is an operation in which it is very easy to obtain indifferent results, and very difficult to obtain uniformly good results. Months of specialised training are necessary to produce an expert welder, during which time considerable specialised knowledge must be acquired, and this knowledge cannot be complete without a thorough grasp of the chemical aspect of the materials and operations concerned. The chemical aspects of welding have been discussed in varying detail in most manuals of welding, yet to the writer's knowledge no attempt has hitherto been made to collect this information in comprehensive form, nor yet to convey the complexity and diversity of the chemical problems which have confronted research workers and those manufacturers who set out to supply the needs of the welding industry. It is the chief object, therefore, of this paper to present this data and to emphasise the importance of what might be called the chemical side of welding.

Before actually dealing with the chemical side, it will not be out of place to make a brief reference to the physical phenomena which accompany welding, namely, fusion, surface tension, diffusion, and expansion and contraction.

Fusion, the medium of autogenous welding, is the change from the solid to the liquid state. For pure substances fusion takes place at a definite temperature, but impurities or other constituents may cause great variation in the melting point. Fusion is always accompanied by the absorption of heat and the quantity of heat necessary to convert unit weight of a solid substance into the liquid form without change of temperature is called the Latent Heat of Fusion. This quantity is of great importance in welding, as this, together with the melting point of the metal, has a bearing on the position of the blowpipe or the current and voltage conditions of the arc.

Surface tension is a property of all liquids and its effects are equivalent to the presence of a hard skin on the surface of the liquid. That liquids have a surface tension can be demonstrated by placing a needle coated with oil carefully on the surface of water. Not only will the needle float, but its weight will depress the surface of the water so that the needle will lie in a hollow. Surface tension has to be overcome before a complete weld is obtained. The presence of oxide generally causes an increase in the surface tension, and suitable fluxes cause a decrease, thus facilitating the operation. On the other hand, surface tension becomes an important factor in "overhead" welding. For example, in welding steel with the oxy-acetylene process the surface tension of the metal is high, which is good for overhead welding, whereas the surface tension of the slag is low and therefore bad for overhead welding. In the case of cast iron the surface tension of the metal is low and that of the slag high. Any welder knows that it is practically impossible to make an overhead weld on cast iron if a good flux is used, because the flux produces a slag melting at a low temperature and thus exposes the metal. In downward arc welding with a long arc, the forces of surface tension and cohesion tending to retain the globule at the electrode are overcome by the weight of the globule; on the other hand, when using a short arc the forces of surface tension and adhesion at the plate surface assist the gravitational force in drawing the globule to the plate. In overhead welding with a short arc the forces of surface tension and adhesion at the plate overcome the combined forces of gravitation, cohesion and surface tension acting to hold the globule to the electrode surface.

Diffusion is the natural tendency of substances in solution to distribute themselves uniformly. The subject of diffusion of metals in metals has been closely studied. Diffusion occurs in welding in two ways. If the composition of the deposited metal differs from that of the base metal, diffusion will take place, tending to equalise the difference. Similarly, if any ingredient is removed by volatilisation or oxidation, diffusion will again take place. In either case, the composition in the vicinity of the weld will not be identical with that of the base metal.

The property of expansion and contraction of metals on heating is well known, although it is not generally realised that in welding operations the forces of expansion and contraction cannot be successfully resisted mechanically. Where the forces are not free to act they manifest themselves by distortion and failures, and the problems arising out of these phenomena are peculiar to every piece of work and should always receive careful attention. The methods commonly employed to equalise or control expansion and contraction stresses are partial or total preheating, heating restraining parts, bending or dishing, &c., &c.

Having briefly dealt with the more important physical aspects of welding which relate to changes of state or condition, we now come to the changes of composition which lie wholly within the realm of chemistry. It is obvious that the net result of physical changes is comparatively small once the metal returns to the normal temperature; yet the chemical changes, as will be seen later, produce great differences in properties and composition, and these are permanent. It must also be admitted that the ultimate object is to produce no chemical change, but this goal cannot be attained unless the possibilities, the intermediate stages and the necessary remedies are fully appreciated.

Oxidation and Reduction.—The principle which governs nearly all the reactions involved in welding is the principle of oxidation and reduction, and it is much to be regretted that many welders refer indiscriminately to "oxide," "deoxidising" and "carbonisation" without comprehending the true significance of these terms, and without understanding their mutual relationship.

In its simplest form oxidation is the process in which oxygen combines with a metal to form an oxide; similarly, reduction is the process in which the oxygen is removed from an oxide, the metal being liberated. There are, however, varying degrees of oxidation and reduction, and any transition from a lower to a higher state of oxidation constitutes an oxidation. *Vice Versa*, a transition from a greater to a lesser degree of reduction is an oxidation process. Thus in carbon steels, if a certain amount of iron carbide is converted into metallic iron oxidation has taken place although no oxide of iron may be produced, and when steps are taken to prevent decarbonisation, it should be regarded chemically exactly similarly to the prevention of oxidation.

Oxidation and reduction always take place side by side and exactly to the same extent. It therefore follows that a reducing agent will combat the effects of oxidation, but it must be remembered that in reducing, the agent itself becomes oxidised, and the nature and chemical properties of the compound so produced must always be considered.

From the point of view of welding we have to consider the metal itself as the neutral point in the scale of oxidation and reduction. This is most unfortunate, for in the wider chemical sense the metals which the welder generally handles are by no means the true neutral points. It should be mentioned that this neutral point varies according to the element. Thus for gold the metal itself marks the neutral point, whereas for aluminium it is the oxide, alumina (Al_2O_3), and for sulphur it is sulphur trioxide (SO_3). This fact, coupled with the 20 per cent. of oxygen in the atmosphere, makes it clear that the welder is working under conditions which are, chemically speaking, artificial. Furthermore, the presence of oxygen in the atmosphere tends to nullify the effect of many reducing agents, since it is obviously easier for the reducing agent to combine with the unlimited supply of free oxygen than with oxygen which is bound in combination with a metal.

Natural laws ordain that many oxides shall be extremely stable. Nature always tends to move towards equilibrium or stability, and in view of the enormous quantity of oxygen which exists it is not surprising that so many oxides should possess a high degree of stability.

In illustration of the varying degree of stability of metallic oxides let us consider the extreme cases, viz., gold and sodium. Gold is not affected by the atmosphere whereas sodium is rapidly oxidised at normal temperatures. Gold oxide slowly decomposes into metallic gold at normal temperatures, whereas no amount of heating will convert sodium monoxide (Na_2O) or even sodium peroxide (Na_2O_2) into metallic sodium. The properties of all the other metallic oxides lie between these two extremes; descending in order from the noble to the base metals the temperature at which atmospheric oxidation begins gradually falls and the temperature at which the oxide decomposes rises rapidly. Having thus dealt briefly with the principles underlying the formation of oxides, let us consider the properties of the individual metallic oxides more generally encountered.

Metallic Oxides.—Iron forms three oxides, which, placed in their order of oxidation, are as follows: Ferrous oxide (FeO), ferroso-ferric oxide or magnetic oxide (Fe_3O_4), and ferric oxide (Fe_2O_3). Ferric oxide, which contains 30 per cent. of oxygen, is encountered in a hydrated form in the familiar rust. It is also produced when cutting with the oxy-acetylene flame and an excess of oxygen is used. Since the magnetic oxide Fe_3O_4 contains only 27½ per cent. oxygen, the formation of Fe_2O_3 in cutting unnecessarily increases the cost on account of the extra oxygen which is required. Magnetic oxide of iron, or scale, is the oxide formed during the welding operation. It is formed on iron when the temperature is raised to incipient redness and is produced very rapidly on the exposed surface of the molten metal. Magnetic oxide melts at a temperature considerably lower than the melting point of iron and of most steels, and it has a solubility of 1·1 per cent. in the molten iron. When iron or steel is heated, say, with a blowpipe, at a certain temperature the heated surface is covered with a layer of oxide. This oxidation may be brought about in several ways, and if the heating be continued the layer of oxide melts whilst the material on which it rests remains in the solid state. If the heating is continued until the metal itself melts, the molten iron or steel can be readily distinguished from the molten oxide because it is less fluid and less brilliant. It is therefore easy to recognise whether the melting is that of the oxide or the metal, yet beginners are apt to overlook the fact that when the metal commences to "sweat" it is only the oxide which has commenced to melt. The melting of welding wire on to surfaces which only show superficially the symptoms of fusion produces very bad adhesion. The oxide is perfectly stable to heat, being neither decomposed into iron or oxidised in the presence of oxygen to Fe_2O_3.

The welding of commercial nickel must be regarded as a difficult proposition. The difficulty in the case of nickel is that the molten metal readily occludes carbon-monoxide and other gases, which causes it to swell up and become spongy. A patent has been taken out for the welding of nickel in the presence of carbon or a carbonaceous material. Nickel oxidises rapidly at high temperatures, forming nickel oxide, an infusible powder. Many welders will be familiar with the formation of this oxide under the name of "burning out the nickel," an alleged process for welding nickel steels without a flux.

Copper forms two oxides—cuprous oxide or copper suboxide (Cu_2O), a bright red powder, and cupric oxide or black copper oxide. These oxides are readily formed by the action of heat on the metal in the presence of air. There has been considerable controversy on the constitution of the oxide formed in welding, and the problem has been further complicated by the high solubility of the oxide in the molten metal, viz., 4·4 per cent. The question is not one of overwhelming importance, but it may be worth mentioning that whereas copper suboxide normally decomposes at 120 deg. C., the large excess of metallic copper present under welding conditions may possibly induce the formation of copper suboxide even at high temperatures, according to the equation:—

$$CuO + Cu = Cu_2O.$$

Copper Oxide and Copper yield Copper Suboxide.

Both oxides are easily converted into the metal by nearly all reducing agents, but their reduction is hindered by the high solubility of the oxide in the molten metal and the delicate nature of the metal renders the choice of the reducing agent a matter of great importance. In welding practice special precautions are taken to prevent the formation of copper oxide, at an early stage of the operation, and these will be discussed later.

Aluminium oxidises in air to alumina (Al_2O_3), with great rapidity at all temperatures. Oxidation being confined to the exposed surface, a film of alumina is formed over the metal, thus preventing further oxidation. This film of alumina is the cause of aluminium vessels being so resistant to many corrosive liquids. Alumina is a white amorphous powder which melts at 2,020 deg. C., as against 657 deg. C. for the metal. It will thus be seen that alumina remains in solid form throughout the welding operation and prevents the union between the base and the deposited metal. The true welding of aluminium is therefore impossible without the use of a suitable flux to remove, or prevent the formation of, oxide. In view of the fact that alumina is absolutely stable to heat and that a temperature equal to that of the electric arc is necessary before it is affected by reducing agents, no attempt is made to effect reduction during welding, the main object being to prevent oxide formation as far as possible and to remove completely all the oxide that is formed, and for this purpose a flux of very high efficiency is required.

So far we have dealt only with the pure metals and have made no mention of alloys. It will suffice to say that the oxidation of alloys is approximately equivalent to the sum of the oxidation phenomena of its constituents. One point of importance is that zinc, an ingredient in brasses and bronzes, boils at 918 deg. C. and the oxide volatilises before it melts.

Non-Metallic Oxides.—The oxidation of the non-metallic elements encountered in welding is somewhat simpler. Oxidation takes place readily, and in most cases the products are gases. The most important non-metallic element is carbon which forms carbon monoxide (CO) and carbon dioxide (CO_2), both gases. Carbon monoxide possesses powerful reducing properties under certain conditions of temperature, but, unfortunately, welding temperatures are generally beyond the limit, and so carbon monoxide has little or no reducing effect.

Unprotected welds made on iron and steel always show a loss of carbon due to oxidation. Diffusion comes into play, tending to equalise the distribution of carbon, and thus the mechanical properties of metal that has been melted are affected.

Sulphur is at all times an undesirable ingredient, and is oxidised to sulphur dioxide (SO_2), a gas. In iron containing a high percentage of sulphur, or more particularly where the sulphur eutectic has segregated, or separated out, the oxidation of sulphur takes place with explosive violence sufficient to scatter the molten metal in all directions.

Phosphorous, another undesirable non-metallic element, is, in most cases, converted into phosphorous trioxide (PO_2O_3) and phosphorus pentoxide (P_2O_5). These combine with water vapour to form phosphoric acid, which is corrosive and must be removed.

Silicon occurs in two allotropic forms, a brown or yellow amorphous powder, and a hard black or grey crystal. The amorphous form is readily oxidised to silica (SiO_2). It is the crystalline form, however, which generally occurs in metals, and it is extremely difficult to oxidise this form of silicon with air or oxygen. Silica is an extremely stable substance which cannot be decomposed by the action of heat. It is unattacked by all acids, except hydrofluoric acid, but it is acted upon by alkalies with the formation of silicates.

There is one reaction of the element silicon which is of the utmost importance, and it is as follows:—

$$Si + CO_2 = SiO_2 + C.$$

Silicon and Carbon Dioxide yield Silica and Carbon.

This reaction has been extensively used in the oxy-acetylene welding of cast iron. A welding rod of high silicon content is used and carbon dioxide is supplied either by a flux containing carbonates, which decompose on heating to give CO_2, or from the combustion of the acetylene.

Flame Combustion—Electric Arc.—At this stage a brief examination of the phenomena accompanying the combustion of acetylene will not be irrelevant, especially as the oxidising and reducing properties of the oxy-acetylene flame have been the subject of much discussion. The complete reaction is represented by the equation:—

$$2C_2H_2 + 5O_2 = 4CO_2 + 2H_2O.$$

Acetylene and Oxygen yield Carbon Dioxide and Water Vapour.

from which it will be seen that one volume of acetylene requires 2½ volumes of pure oxygen for complete combustion. Most welders will be aware that the practical ratio is 1 volume of acetylene to between 1·1 and 1·7 volumes of oxygen, depending on the pressure of the acetylene and the efficiency of the blowpipe, and a little investigation will reveal the cause of this discrepancy.

In reality the combustion takes place in two distinct stages. Stage I consists in the breaking down of acetylene

* Paper read before the Institution of Welding Engineers, on Tuesday, February 12, 1924.

and the formation of hydrogen and carbon monoxide as follows :—

$$C_2H_2 + O_2 = H_2 + 2CO.$$

Acetylene and Oxygen yield Hydrogen and Carbon Monoxide.

Stage II consists in the combustion of the products from Stage I, carbon monoxide being oxidised to carbon dioxide and hydrogen to water vapour, viz. :—

$$CO + O = CO_2.$$
$$H + O = H_2O.$$

The explanation of the discrepancy between the practical and theoretical quantities of oxygen lies in the fact that the bulk of the oxygen in Stage II is derived from the atmosphere. Thus the properly adjusted oxy-acetylene flame, burning at the nozzle of a well-designed blowpipe, automatically obtains sufficient oxygen from the atmosphere to complete combustion, and it therefore follows that if excess of oxygen arrives at the blowpipe nozzle from the cylinder, the excess will impinge directly on the metal causing intense oxidation. If, on the other hand, insufficient oxygen is supplied, there is an excess of acetylene and carbon is produced, probably according to the equation :—

$$C_2H_2 + CO = H_2O + 3C.$$

Acetylene and Carbon Monoxide yield Water Vapour and Carbon.

As all the components in the combustion of acetylene are gases moving at high speeds, it is obviously unreasonable to expect Stages I and II to be sharply divided. The combustion may, therefore, be said to take place in three zones, as illustrated in Fig. 1, annexed.

Zone I is the luminous zone and contains all the components of Stage I., viz., acetylene, oxygen, hydrogen, and carbon monoxide, the reaction not being complete at the end of Zone I. Zone II is completely non-luminous and in it Stage I is completed and Stage II also begins. The atmospheric oxygen comes into play at the beginning of Zone III, where the reaction is completed. It is Zone II that is of most interest to the welder, as all welding operations are carried out at various positions in this zone, the nature of the metal, its melting point, and the dimensions being important factors in fixing the best position.

With regard to the temperature of the oxy-acetylene flame, the determination of the temperature is a matter of great difficulty, no authorities have yet been able to agree about it. The values given for the highest temperature vary from 2,000 deg. C. to 4,000 deg. C. and these two values can be taken as extreme values not obtainable in ordinary practice. The importance of using gases of the highest degree of purity to avoid the reduction of temperature and loss of heat has been demonstrated by Mr. C. Bingham in a paper on "Impurities in Acetylene." It is impossible to fix temperatures without having definite conditions but with good apparatus and pure gases well balanced, the temperature existing in the flame will attain 3,000 deg. C. but does not exceed 3,500 deg. C. The diagram (Fig. 2) will serve as an approximate indication of the temperature at various points along the axis of the flame, from which it will be seen that the temperatures in Zone II lie between 2,000 deg. C. and 3,000 deg. C.

The composition of the gases in Zone II is as follows :—Two parts carbon monoxide and one part hydrogen with very small quantities of acetylene, oxygen, carbon dioxide, and water vapour. The following analysis is purely hypothetical, but will serve to illustrate what might be anticipated :—

	Per cent.
Carbon monoxide	60
Hydrogen	30
Carbon dioxide	4
Water vapour	4
Acetylene	1
Oxygen	1

It would appear at first sight that a gaseous mixture of such composition should possess powerful reducing properties, but two points must be considered. Firstly, the reducing properties are completely destroyed in Zone III, and, secondly, at the temperature of 2,000 deg. C. to 3,000 deg. C. of Zone II, the stability of all common oxides becomes so great as to render them unreduceable by carbon monoxide or hydrogen. This fact destroys the fallacy, which is found even in recent books on welding that the oxy-acetylene flame is a reducing flame and consequently eliminates the necessity for fluxes. In the opinion of the writer, the only active constituent in Zone II is the very small quantity of oxygen, which gives the zone a feeble oxidising action. Whether this opinion be right or wrong, it is a very safe assumption for the welder to make.

In the electric arc the conditions are greatly simplified and it is safe to consider the arc as a neutral source of heat provided it is properly protected. If oxygen is allowed to pass directly through the arc, however, it assumes intensely oxidising properties, as is amply illustrated by the modern process for the manufacture of nitric acid, in which a mixture of oxygen and nitrogen is caused to pass through an electric arc, and nitrogen which is usually very difficult to oxidise, is converted into nitric oxide. It may be of general interest to mention that the temperature of the arc is about 3,500 deg. C.

In both processes of welding the chief causes of oxidation are to be found, firstly, on the rod before it actually reaches the high temperature zone, and, secondly, on the work and the deposited metal immediately after the high-temperature zone.

So far all the information points decisively to the fact that unless very special measures are taken to prevent it, oxidation is inevitable; and so having dealt in fairly full detail with the disease, let us turn to the consideration of the remedies.

Oxidation: Its Prevention.—It is hardly necessary to deal in any great detail with the necessity for preventing oxidation. Most welders are familiar with the entire lack of tensile strength and elongation possessed by metallic oxides. The heterogeneous nature of a weld containing oxide inclusions is also familiar.

The alteration in mechanical properties due to the oxidation of carbon in the welding of cast iron is also familiar; in brief, oxidation represents all that is bad and undesirable for the welder.

The prevention of oxide formation is approached from two distinct directions, chemical and physical. The chemical method makes use of suitable reducing agents which decompose any oxide formed, and the physical or protective method, which, firstly, protects the welding rod, secondly, protects the deposited metal, and, thirdly, dissolves any undecomposed oxide. The reducing agent may be added to a flux or be incorporated in the welding wire or rod, but in this latter case the use of a suitable flux is still essential, to prevent local oxidation.

Reduction.—Reducing Agents.—A large variety of reducing agents have been used with varying degrees of success. One of the least successful and yet one which is still in extensive use is carbon. The reducing action of carbon at the temperature of the welding operation is extremely small. This is partly accounted for by stability considerations, partly by the readiness with which carbon oxidises in the atmosphere, and partly by the fact that it is carbon monoxide and not the element which actually brings about reduction. Added carbon is also inefficient in replacing carbon removed by oxidation, as, for example, in the welding of cast iron.

Fig. 1. CHARACTERISTICS OF THE OXY-ACETYLENE FLAME

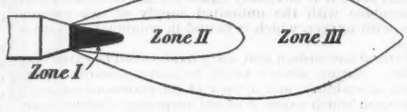
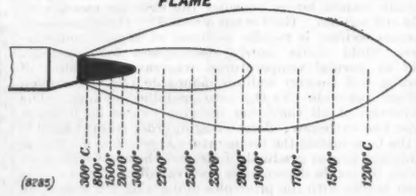


Fig. 2. TEMPERATURES IN THE OXY-ACETYLENE FLAME



Silicon is not a reducing agent in the proper sense of the word. Reference has already been made to its reaction with carbon dioxide in the welding of cast iron. The properties of ferro-silicon are similar to those of silicon. Calcium silicide, however, possesses very definite and powerful reducing properties on account of the presence of the element. Further, if calcium silicide is decomposed, the silicon obtained is the yellow amorphous variety which is readily oxidised. The final product when calcium silicide is used for reduction, is calcium silicate which possesses valuable slagging properties.

Aluminium is one of the most powerful reducing agents obtainable, and if properly protected, gives very satisfactory results. A most ingenious application of aluminium in this connection is to be found in the quasi-arc electrode, where a fine aluminium wire is wound on the rod, a layer of asbestos being wound over the whole. The reducing properties of aluminium have been fully exploited in the Thermit-welding process and the Goldschmidt patents for the preparation of metals and ferro-alloys.

The Thermit reaction may be summarised by the following equation :—

$$3Fe_3O_4 + 8Al = 4Al_2O_3 + 9Fe.$$

Iron Oxide and Aluminium yield Alumina and Iron.

The reaction applies equally well to the oxides of nickel, chromium, manganese, silicon, molybdenum, tungsten, vanadium, titanium and zirconium, and it proceeds with considerable violence and the evolution of enormous quantities of heat, so that the whole of the contents are melted and the metal separates at the bottom from the slag. By means of this reaction it is possible to prepare alloys of almost any composition.

Another highly successful reducing agent is the metal titanium. It has been used as a scavenger with much success in the steel industry and is equally efficient in welding. Its action is based on the formation of titanium dioxide, thus :—

$$Fe_3O_4 + 2Ti = 3Fe + 2TiO_2.$$

Iron Oxide and Titanium yield Iron and Titanium Dioxide.

It possesses a further advantage in that titanium dioxide is extremely light and separates from the molten metal with great facility. The oxide is also readily soluble in the alkaline slags produced by the fluxes generally used in the welding of iron and steel.

Phosphorus has a limited use as a reducing agent in welding. It is very efficient but should be used with great caution, as it forms stable phosphides with most of the metals, and if present in excess of the requisite amount, will bring about the separation of the phosphorus eutectic which weakens a weld. This point is brought home in the welding wire for copper welding. A heterogeneous wire or one containing only a slight excess of the correct quantity of phosphorus leads to defective welds.

Slags.—We now have to consider the question of the removal of the products resulting from the use of reducing agents. These are silica, alumina, phosphoric acid and titanium dioxide, and their removal is accomplished in a manner very similar in principle to methods used in the purification of the industrial metals, although the great difference in temperature necessitates the use of very different materials. In welding operations fluxes are used which produce a slag which not only removes the by-products of reduction but also the oxide of the metal which is being welded.

Slag formation and the chemical properties of welding slags is a subject of the greatest complexity, but a very necessary subject for manufacturers of fluxes. The earliest flux in history was the sand used in smith's welding, in which case a complex iron silicate is formed. This silicate, however, decomposes below the melting point of iron and therefore sand alone is unsuitable as a welding flux. The silica slags, however, are of great value in welding and they fall into three classes: (1) soda-silica slags; (2) magnesium-silica slags, and (3) soda-calcium silica slags. The soda-silica slags are produced by the use of sodium silicate ($Na_2Si_4O_9$) employed in various forms for welding mild steel, cast steel and nickel steel. They dissolve Fe_3O_4 quite readily and form a complex sodium-iron silicate. The magnesium-silica slags are produced when asbestos is used. The soda-calcium silica slags are products closely akin to glass, and their use is confined to flux-coated electrodes.

All these slags dissolve Fe_3O_4 readily, the soda-silicate variety being the most active in this respect, and they also remove alumina with the formation of alumino-silicates similar to natrolite ($Na_2O.Al_2O_3.3SiO_2$) or in the case of magnesium and calcium ($CaO.Al_2O_3.2SiO_2$) anorthite.

A second variety of slags used in welding are produced from the element boron, generally encountered as borax ($Na_2B_4O_7$) or boric acid (H_3BO_3), and here the action on oxides is very much simpler. At high temperature both borax and boric acid yield boric anhydride (B_2O_3) which combines directly with the oxides of copper, cobalt, chromium, iron, nickel and manganese. Thus in the case of copper oxide and borax we have the reaction :—

$$Na_2B_4O_7 + CuO = Cu(BO_2)_2 + 2NaBO_2$$

Borax and Copper Oxide yield Copper Borate and Sodium Metaborate.

All the slags indicated in the last three paragraphs have a high melting point and a very high boiling point, and the problems of flux manufacture have not yet been solved. The melting point of the flux must be adjusted to suit the conditions of welding; the melting point of the slag must be adjusted to come well below the melting point of the metal, and the specific gravity of the slag must be adjusted so as to come away clear of the metal.

Slag formation in aluminium welding is a separate subject. The chlorides of sodium, potassium and lithium form the basis of all the reliable fluxes for aluminium welding, and there is every reason to believe that the activity of such fluxes is due to the formation of meta-aluminates of the type KO.AlO. The reaction is difficult to put on paper, but there is no evidence in favour of the theory that alumina is mechanically soluble in the molten flux. The operation is complicated by the low specific gravity of the molten metal, and it is essential that the slag should separate completely from the molten metal.

Reference may be made here to the properties of cryolite $AlF_3.3NaF$, which has been used as a flux both in aluminium manufacture and welding. It is unsatisfactory in welding on account of its high melting point, 977 deg. C., so that it solidifies before the molten metal. The ideal flux should melt at a lower temperature than the melting point of the metal or alloy to be welded and should possess, after fusion, sufficient fluidity and a sufficiently low specific gravity as to avoid all chance of its becoming entangled in the molten metal and remaining there after solidification, thereby setting up corrosion. The flux when melted under the action of the blowpipe should not, however, be so fluid as to run off and leave the surface of the metal exposed to the oxidising action of the atmosphere or of the gases of the flame. It should on the contrary form a viscuous varnish on the surface of the metal and previous to varnishing it should not be easily blown away by the force of gases emerging from the blowpipe, but form an uninterrupted protective layer preventing local re-oxidation of any part of the metal previously deoxidised by the action of the flux.

Fluxes.—Having thus described the general chemical and physical phenomena in welding we may now turn to the complete consideration of the conditions encountered in welding practice.

Welding cast iron by the electric arc cannot yet be described as wholly satisfactory owing to the variation in physical properties frequently met. At present welding with a graphite electrode gives good results, but there is scope for a great deal of investigation in this direction and this is at present being undertaken.

Welding cast iron by the oxy-acetylene process, however, can be carried out to perfection. The ingredients of the flux are sodium carbonate and bicarbonate, borax and silica. A rod of high silicon content has been extensively used, for reasons already stated, but recent research has provided rods of special composition, which give much better results than the silicated rods. One of special interest is a rod containing titanium in such quantity as to prevent internal oxidation of both iron and carbon. The flux ingredients are designed to glaze the rod forming an excellent protective coating. The silica combines with the sodium carbonate, giving sodium

silicate, which in turn combines with the borax, giving sodium borosilicate with free borax, a slag which is a highly efficient solvent for iron oxide.

Welding mild steel with the electric arc is extremely successful, but in any case a protective flux should be used. The qualifications for this flux are that it should melt at the same rate as the electrode, it should contain a reducing agent and form a suitable slag. A large number of patents have been taken out on this subject, asbestos and calcium salts occurring in most of them, and it would seem that the chief function of the flux is to form a protecting sleeve of gases for the arc.

Mild steel can be welded with equal success by the oxy-acetylene process and the problem of eliminating oxide when welding iron and steel is a very difficult one and has received considerable attention for many years. It has been shown that its reduction by the flame of the blowpipe is not possible and it is therefore necessary to fall back on some form of reducing agent.

Numerous reducing agents are used in the metallurgical industry and experiments have been made with most of them in one form or another. In the welding industry certain of these agents have been used in the form of powders or as an alloy with the welding wire. The use of deoxidising fluxes in the form of a powder have many disadvantages when used for welding steel. The addition of deoxidising agents to the welding wire is difficult to attain because most of these agents have a very low density and do not alloy well with iron and steel.

It has been found that a deoxidising material in the form of a liquid gives excellent results when welding steel. One product on the market is specially prepared for use with welding wire which does not contain deoxidising elements. It is recommended for use in repair work, for welding sheet metal—especially thick material—and castings. At the high temperature of the flame it slags the oxide, maintains the surfaces clean and prevents inclusion of oxides. It thus facilitates the rapid execution of the weld and, in consequence, reduces to a minimum the overheating effects and thus eliminates local defects. The material is sold in cans containing approximately one and two pints respectively and is applied by means of a brush to the edges of the weld and the welding wire, previous to welding.

Medium and hard steels require careful handling, but indifferent results are obtained, because of the metallurgical phenomena which intervene. A flux similar to that used for cast iron should be employed. It should be remembered that in these steels the carbon which varies from 0·3 per cent. to 1·2 per cent. is present, almost entirely in the combined state, that is as iron carbide (Fe_3C) and its various modifications. It is well known that temperature conditions play a great part in the mechanical properties of solutions of iron carbide, and in fact this forms a separate subject which is familiar to all under the name of "tempering." Provided oxidation is prevented by the use of a flux the measure of success of the operation depends on the right heat and mechanical treatments being applied.

The welding of copper is a simple operation if the right materials are used, and in this connection it is essential to use a properly prepared wire containing phosphorus as a reducing agent. The flux used should consist of boric acid, borax and sodium chloride which protects the rod and removes copper oxide by the formation of copper borate, as already described. The sodium chloride constituent of the flux serves to adjust its melting point.

The welding of brasses and bronze is very similar to the welding of copper, specially prepared rods and a flux of similar composition being necessary. The welder should be thoroughly familiar with the chemical composition of the commoner forms of brasses and bronzes, and should be able to select rods of composition suitable for his purposes.

The welding of aluminium is probably the most difficult proposition which the welder encounters, the rapidity with which alumimiun is oxidised and the character of the oxide being the chief trouble. It is extremely difficult to weld aluminium without a highly efficient flux, and practically impossible on thin sheets. The method of welding without a flux, known in the trade as "puddling," should be looked on as an emergency procedure as films of oxide remain in the weld reducing its strength and leading to cracks and disintegration.

Chemical Control.—Chemical control concerns more the preliminaries than the welding operation itself, and it is essential for a welder to ascertain that all the materials he uses in the form of fluxes, welding wires and rods, gases, &c., have been manufactured under efficient chemical control. Acetylene and oxygen in cylinders are usually delivered in a high state of purity, but those who buy carbide and make their own acetylene have to guard against the two dangerous impurities—sulphuretted hydrogen (H_2S) and phosphoretted hydrogen (PH_3), which if not removed, lead to the formation of the sulphur and phosphorus eutectics which lead to defective welds. In addition an efficient purifier acts as a mechanical filter and prevents particles of dust and moisture reaching the weld. Consumers would be well advised to insist on their carbide conforming to the specification of British Acetylene and Welding Association and should use purifying materials prepared under strict chemical control.

The principle of the action of all purifying materials is one of oxidation. Permanganates, chromic acid and ferric salts all oxidise sulphuretted and phosphoretted hydrogen to sulphuric acid and phosphoric acid respectively, which are readily absorbed by the material. It is of interest to note that chemical means must be employed for the removal of these two impurities, scrubbers being inefficient.

The manufacture of welding wire also calls for the strictest chemical control in every operation, from the raw material to the finished article. This applies particularly to the manufacture of welding wire for copper and its alloys. The phosphorus necessary must be present in a definite percentage, below which oxidation occurs, and above which the phosphorus eutectic is formed, and the preparation of a copper wire containing a definite percentage of phosphorus is not nearly as easily as it sounds.

The preparation of fluxes for high temperature welding operations is an art, and there are three essential conditions for success, viz., (1) that the ingredients be absolutely pure; (2) that the finished flux be absolutely dry, and (3) that the ingredients be perfectly mixed. The first condition necessitates a complete analysis of all raw materials. The second condition necessitates special plant and control tests on the finished fluxes, and the third condition demands expert workmanship and strict attention to detail. Consequently the preparation of fluxes should be left in the hands of the chemical manufacturers whose plant, experience and technical staff renders them alone competent to undertake the task.

The remarks in the previous paragraph apply in the superlative degree to the preparation of fluxes for aluminium welding. All the ingredients of this flux are medium sized deliquescent crystals, *i.e.*, they absorb moisture from the atmosphere. These have to be reduced to a fine dry powder of uniform composition, and this operation has only been achieved after much research and requires very special plant, suitable for this purpose alone.

Conclusion.—There are many other points of interest and importance which might be mentioned in this paper. It will be gathered that the crux of the chemical aspect is the removal of, and prevention of, foreign inclusions in welds, which are the chief cause of failures. [In this connection the author exhibited a few slides to indicate how such failures commence may be of interest.]

In conclusion, the writer has not attempted to probe too deeply into the subject as it is impossible to do so in the limited time at his disposal. In fact, nearly every single compound mentioned has formed the subject of a number of text books, but it is, of course, quite unnecessary for the welder to assimilate the contents of all these. A clear conception of the chemical aspects of welding, however, is an essential part of the welder's equipment, and this the writer has attempted, with success he trusts, to present.

CATALOGUES.

Crane-control Panel.—A crane-control panel of the relay type with inverse time element overload relays for the protection of the motors is dealt with in a catalogue received from Mr. George Ellison, Perry Bar, Birmingham.

Reduction of Noise and Vibration.—Various methods of preventing the transmission of noise and vibration from engines and other machinery are dealt with in a catalogue issued by Messrs. W. Christie and Grey, Limited, 4, Lloyd's-avenue, London, E.C. 3.

Mechanical Stoker.—A catalogue illustrating the application of the Riley Stoker to various types of water-tube boilers and describing the construction and action of the machine is to hand from Messrs. Charles Erith and Co., Palace-chambers, Bridge-street, London, S.W. 1.

Lubricating Oils.—Special oils for looms and spindles in various qualities for high or low speed bearings are dealt with in a 16-page pamphlet issued by Shell-Mex, Limited, Kingsway, London, W.C. 2. The pamphlet contains much useful information on the subject of lubrication.

Centrifugal Pumps.—A catalogue of centrifugal circulating pumps with horizontal or vertical shafts is to hand from Messrs. Gwynnes Engineering Company, Limited, Hammersmith, London. Fourteen standard sizes are listed and the capacities cover a range of 3,000 to 18,500 gallons per minute.

Water Softening.—A four-page circular illustrating the Lassen-Hjort automatic apparatus for measuring the hard water of the softening re-agent and for actuating the stirrers and also including a number of general views of filtering and softening installations is to hand from United Water Softeners, Limited, Imperial House, Kingsway, London, W.C. 2.

Turbo-Generator.—The Brush Electrical Engineering Company, Limited, Loughborough, has issued an interesting 10-page catalogue of their 5,000 k.w. generator, containing figures of the economies effected at Walsall, Warrington and Stockport, where these machines are in operation. At Walsall the coal consumption is given as 3·15 lb. per unit delivered to the mains.

Electric Conduits.—A remarkably comprehensive catalogue of light and heavy conduit tubes; switch, ceiling and wall plug boxes; earthing devices; bases and connectors; watertight fittings; special tools; and the variety of small details required by contractors in fitting up wiring installations is to hand from the General Electric Company, Limited, Kingsway, London, W.C. 2.

Rubber Tyres.—Prices and particulars of rubber cushion tyres for tractors, heavy haulage traction engines and road locomotives, and for wheels ranging from 3 ft. dia. to 7 ft. dia. are given, in a special catalogue received from Messrs. John Fowler and Co. (Leeds), Limited, 113, Cannon-street, London, E.C. 4. Twin tyres are fitted on wheels of 5 ft. dia. and upwards. The prices quoted are for new wheels and tyres complete, or for supplying new traction engines with rubber-tyred wheels instead of the usual wheels with steel treads.

Pumps.—A new edition of their catalogue of pumps for land installations has been received from Messrs. G. and J. Weir, Limited, Cathcart, Glasgow. The types described include a twin vertical pump for feeding water-tube boilers, "small standard" and "standard" feed pumps, turbo-feed pumps, and "standard" general pumps. A triple expansion pumps capable of delivering over 200,000 gallons of oil a day against a pressure of 600 lb. per square inch, and a compound pump delivering 8,000 gallons of oil per hour against a pressure of 1,000 lb. per square inch are illustrated. The catalogue gives particulars of stop valves and fittings generally, and contains some useful technical information.

Briquetting Plant.—A series of machines mainly used for briquetting small coal, coke, ores, &c., is dealt with in a catalogue received from Messrs. William Johnson and Sons, Limited, Armley, Leeds. Various machines for making small egg-shaped fuel blocks, and the usual large rectangular blocks, are included, together with some for treating peat and lignite similarly. Other machines shown in the catalogue are for cracking, mixing, measuring and heating the materials, and there are a number of powerful presses, as well as a self-propelling machine, on two four-wheeled bogies for picking up and briquetting the small coal, cinders, &c., which accumulate on the railway track. The high price of coal gives a commercial opening for this class of machinery.

Vertical Boilers.—Messrs. Ruston and Hornsby, Limited, Lincoln, have issued a catalogue of their new vertical boiler, named the "Thermax." The main features of the construction, which is patented, are the introduction of larger numbers of smaller diameter tubes and the method of grouping these tubes to absorb the heat from the furnace. Although the vertical boiler is not economical in fuel, it is so reliable and convenient in use that it has always secured a large share of favour. The "Thermax" boiler retains the large fire-box and large direct-heating surface, but is said to give better water circulation and greater fuel economy. The boiler is made in 11 standard sizes ranging from 2 ft. 9 in. diameter by 6 ft. 9 in. high to 5 ft. 6 in. diameter by 14 ft. height; all are suitable for a working pressure of 120 lb. per square inch.

Fuel Economisers.—A new edition of their catalogue of fuel economisers for steam power plants is to hand from Messrs. E. Green and Son, Limited, Wakefield. It is over seventy-five years since the first of these economisers was made, and the improvements consist in a constant revision of details rather than any radical departure from the original design. A special construction of joints for very high pressures and a horizontal tube pattern for mounting over water-tube boilers are two developments to meet special conditions of modern practice, but in most cases even now the original vertical tube design is preferred. The firm point out that none of the financial advantages attending the use of economisers are obtained by stressing other parts of the plant, the economiser having the effect of easing and regularising the operation of the whole installation.

Steel Castings.—Users of steel castings will find much useful information in a publication recently issued by Messrs. Edgar Allen and Co., Limited, Sheffield, bearing the title "The Edgar Allen Steel Foundry Book." It explains the essential points that should be mentioned in ordering or in making enquiries for steel castings, and illustrates a large number of castings of all kinds supplied by the firm either in the rough, rough machined or finished machined states. In addition to the ordinary steel castings illustrated, a number of castings in high permeability magnet steel and in manganese steel are also shown, and among the latter are some large bevel pinions in which the keyways have been accurately formed to template by grinding. This publication is an excellent example of trade literature which is well worthy of perusal by all interested in the subject of steel castings.

LLOYD'S REGISTER OF SHIPPING REGISTER BOOK.—To merchants, shipowners, underwriters, and others whose business is in any way connected with ships and shipping, there is probably no more useful publication than the Register Book issued each year in July by Lloyd's Register of Shipping, 71, Fenchurch-street, London, E.C. 3. It gives the names, classes, and other particulars of all vessels classed by the society and by the late Underwriters' Registry for Iron Vessels, as well as of practically all other merchant ships of the world of 100 gross tons and upwards. The book also includes lists of motor vessels, of vessels carrying petroleum in bulk or burning oil fuel, of cable steamers, of vessels fitted with refrigerating machinery, of frozen-meat stores, and of shipowners, while in an appendix issued with the Register Book particulars of docks and harbours in all parts of the world are given, together with lists of telegraphic addresses of firms connected with shipping, of steamers arranged in order of tonnage and speed, and of shipbuilding firms; the last-mentioned list includes the names of all existing vessels built by each firm. Valuable statistics relating to merchant shipping are also included in the appendix. A unique feature in connection with the Register Book, which has been in operation for the whole period of its existence, *i.e.*, for over 160 years, is the system of posting, by which particulars of new vessels are added and data relating to existing vessels are revised each week, so that the book is kept quite up to date at all times. To subscribers who do not adopt the system of posting, reports of additions and alterations to the Register Book are issued gratis at fortnightly intervals. We would particularly direct the attention of all users to two lectures on the Register Book by Mr. F. A. Mayne, delivered at the Gresham College in November and December, 1922, and subsequently reprinted by the society. A careful perusal of these lectures will be of material assistance in enabling them to make the fullest possible use of this most valuable work.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the communicators are given in italics.

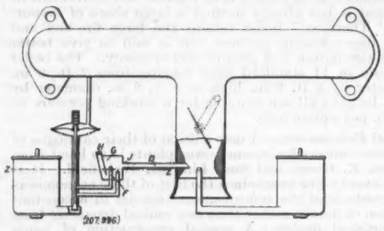
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 1s.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

GAS ENGINES, PRODUCERS, HOLDERS, &c.

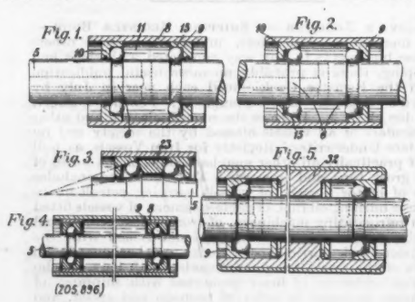
207,986. E. Dodson, Streatham, London. Carburettors. (3 *Figs.*) November 18, 1922.—The invention relates to an improved system for controlling fluid outflow from carburettor nozzles of the kind in which the outlet of the nozzle is located above the normal fuel level in a passage communicating with the induction system and having an air inlet passage whose effective area is less than that of the outflow passage to the induction passage. According to the invention, there is employed in combination with a jet nozzle projecting above the normal liquid level of the supply, a chamber enclosing the nozzle orifice having



an outlet passage for the discharge from the nozzle and also a fixed passage of smaller size for the entry of air by way of a liquid seal. The jet nozzle F is located in a chamber G having a relatively small passage H at its upper part for the entry of air. To this chamber the conduit D is connected at about the level of the top of the jet nozzle F, this being above the normal level of the liquid (represented by the line Z—Z) to avoid any possibility of its being flooded. One or more air-vent holes J may be provided in the upper wall of this conduit D, one preferably near the exit of the conduit, thereby to break up and to aerate the liquid delivered from the nozzle F. (*Accepted December* 19, 1923.)

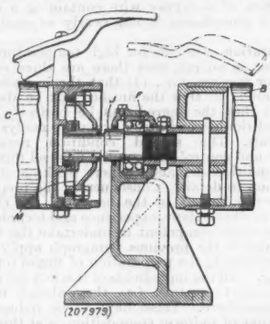
MACHINE AND OTHER TOOLS, SHAFTING, &c.

205,896. B. Shorthouse, London. Ball Bearings. (11 *Figs.*) July 27, 1922.—In a ball bearing for drawing rollers of spinning frames, &c., comprising one or more ball races formed on a spindle or tube and two ball-retaining rings 9, each forming an outer race contained in a sleeve 8, the rings 9 are force-fitted one into each end of the sleeve 8 to confine one or more rows of balls between them and form a unit which cannot easily be dismantled. Additional means for securing the rings 9 may be provided. Each ring 9 is provided with a flange 10, which extends outside the balls to near the spindle or tube, and serves to prevent distortion of the ring and to constitute a dust-excluding and oil-retaining device. In the form shown in Fig. 1, the spindle 5 is provided with two grooves 6, forming inner races for two rows of balls, and the bearing surface 15 of each ring 9 is cylindrical, the flanges 10 serving to position the bearing axially. Lubricant is supplied to the space 11 between the balls. As shown in Fig. 2, the surfaces 15 of the outer races are conical and the flanges do not touch the



balls. The tangents at the points of contact with the inner and outer races are parallel. In Fig. 3, the tangents at the points of contact with the inner and outer races meet on the axis of the bearing, and a loose thrust ring 13 is located between the two rows of balls. The tangents may meet at a point other than the axis of the bearing, and the ring 23 may also serve as a cage for spacing the balls, being provided with projections engaging between the balls. Fig. 4 shows a bearing in which a single row of balls is confined between the two rings 9. For use with wooden drawing roller, the periphery of the sleeve 8 is made polygonal and the roller is forced thereon. In the case of an iron roller, the sleeve 8 has a cylindrical periphery and is secured in the roller by a screw engaging a groove in the sleeve. Fig. 5 shows a cotton roller 32 in which the ends are bored to take the forced-in rings 9. The bearing may be so constructed that it is self-aligning. (*Sealed.*)

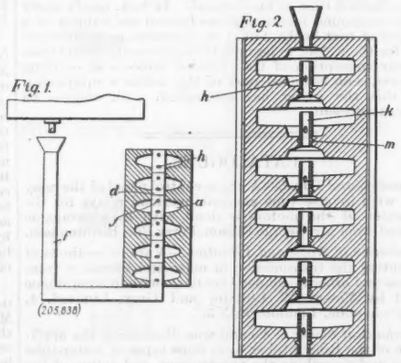
207,979. Never-Stop Transit, Limited, London, B. R. Adkins, Warlingham, Surrey, and W. Y. Lewis, Southend-on-Sea. Supporting Shafting. (4 *Figs.*) November 15, 1922.—The invention relates to means for supporting shafting and is more especially applicable to a bearing support for the adjacent ends of sections of the shafting of a conveying apparatus. According to the invention, a stub shaft J, supported in bearings F, is connected to the main shafting B, C by means of a flexible diaphragm M. When two adjacent ends of sections of the shafting are to be supported, a flexible diaphragm may be employed to connect one or both of the sections to the stub shaft



supported in bearings which are preferably of the self-aligning type. Such an arrangement makes allowance for changes or inaccuracies in the alignment of the shafting, and prevents the shafting or its bearings from being subjected to excessive strains from any cause. (*Accepted December* 19, 1923.)

MINING, METALLURGY AND METAL WORKING.

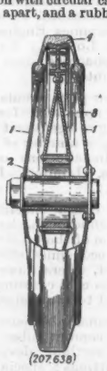
205,838. J. H. Warlow, Junior, Rotherham, and Steel, Peech and Tozer, Limited, Ickles, Sheffield. Casting Steel Ingots. (4 *Figs.*) April, 25, 1922. Ingots and other castings are cast in multiple moulds *a*, fed in succession from a central runner. A number of stacks of moulds may be arranged around a common ingate *f*. The runner is preferably built up of



refractory sections *d*, each having a metal outlet *h* and an air, &c., vent *f*. The moulds may be divided longitudinally or horizontally in various ways. In a modification, the runner may be in discontinuous sections *k*, each provided with a retaining flange *m*. The runners are punched out of the castings after their removal from the moulds. (*Sealed.*)

MOTOR ROAD VEHICLES.

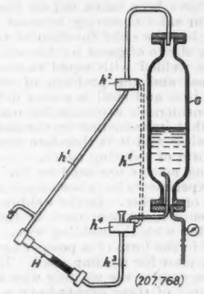
207,638. T. Browett, Hove. Resilient Wheels. (5 *Figs.*) September 8, 1922.—A wheel, according to the invention, comprises the combination with circular carriers 1, 1 mounted on a hub or hubs 2 and spaced apart, and a rubber tyre 4 of "U" section



secured at its edges to the peripheries of the carriers, of a third member 8 disposed between the two carriers bearing at its periphery on the inner part of the tyre opposite its tread and free to move relatively to the hub or hubs radially in all directions. (*Accepted December* 12, 1923.)

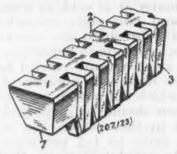
STEAM ENGINES, BOILERS, EVAPORATORS, &c.

207,768. W. H. Watkinson, Liverpool. Water-Level Gauges. (1 *Fig.*) June 1, 1922.—The invention relates to water-level gauges of that type in which a gauge glass containing a heavy liquid has its upper end connected by a liquid filled tube to the boiler steam space and its lower end connected to the boiler water space. According to the invention, a gauge glass H, partly filled with a liquid heavier than water, has its respective ends connected to the vessel the liquid level in which has to be indicated, as follows: Assuming the vessel to be a boiler. The upper end of the gauge glass H is connected with the steam space G through a pipe h^1 and through a chamber h^2 of large sectional area, this chamber, which will be termed the upper chamber, being situated at any level above that of the water in the boiler, and at any distance therefrom. The connection of the lower end of the gauge glass H with the water space of the boiler is also made through a pipe h^3 and through a chamber h^4 of large sectional area, the chamber h^4 in this case, which will be referred to as the lower chamber, being below the level of the water in the drum and at any distance from it. The heavy liquid partly fills the gauge glass, entirely fills the tube h^3, and nearly fills the lower chamber h^4. The upper part of the gauge glass, the pipe and



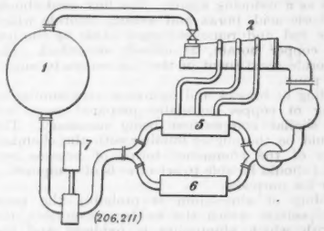
the upper chamber h^2 are filled with water at least up to the point of connection between this chamber and the pipe leading to the steam space of the boiler drum. The heights of the two chambers relatively to one another and to the gauge glass depend on the relative density of the two liquids. In some cases the two chambers are connected to each other by means of a short circuit pipe h^7. (*Accepted December* 12, 1923.)

207,123. G. H. Collins, Brentford. Fire Bars. (4 *Figs.*) April 26, 1923.—The invention relates to fire-bars for boiler-furnaces. A fire-bar, in accordance with the invention, has the following features in combination, viz.: a central body part or bar proper having a flat upper surface 1, a like number of vertical ribs 3 on each side extending the full depth of the bar, those on



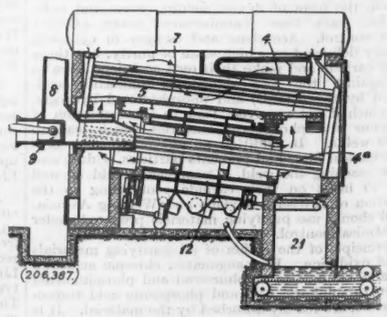
one side being staggered in relation to those on the other, and having their side faces inclined so that the space 2 between adjacent ribs gradually increases in area from the top downwards and their outer faces tapering from practically the top to the bottom, and shoulder portions 7 of the same shape at each end of the body part or bar proper, whereby the bars are reversible. (*Sealed.*)

206,211. J. Swinburne, Westminster. Steam Turbine Plants. (1 *Fig.*) July 28, 1922.—In a condensing steam turbine plant, a portion of the feed water is sent through a heater 5, supplied with steam tapped from one or more operative stages of a turbine 2, and the other portion through a heater 6 heated by flue



gases, the whole passing by the pumps 7 to the boiler 1. The quantity passing through the economiser may be regulated to ensure that its rise in temperature is approximately equal to the fall in temperature of the flue gases and that the latter is constant for all conditions of working. (*Sealed.*)

206,387. J. S. Atkinson, Westminster, and Stein and Atkinson, Limited, Westminster. Steam Generator Furnaces. (1 *Fig.*) December 4, 1922.—The water tubes 4a of a steam generator are arranged in close relationship with a grate, which comprises a slotted or perforated and jacketted fuel carrier 12, to one end of which are connected a fuel supply 8, 9 and a combustion chamber 5, an ash receiver 21 being disposed at



the other end. Air is supplied through the jacket and slots, and the carrier, which may be cylindrical or trough shaped, is rocked or rotated to cause longitudinal travel of the fuel. One bank of tubes 4 traverses the combustion chamber 5 and is external to the grate, and the bank of tubes 4a passes longitudinally of and through the fuel-carrier. The ash end of the fuel-carrier is connected by a damper-controlled flue with the combustion chamber. (*Sealed.*